Byland Abbey
North Yorkshire

Geophysical Survey

April 2009

Report No. 1941

English Heritage

Byland Abbey
North Yorkshire

Geophysical Survey

Summary

A geophysical survey, comprising both magnetometer and earth resistance, was carried out over part of the former precinct of Byland Abbey, North Yorkshire (Monument No. 13279) as part of a wider research project investigating the area through analytical earthwork survey. Three possible structures have been identified in both surveys although all correlate to a certain extent with the mapped earthworks. In general the resistance survey has provided the most detail with all the major earthworks clearly defined as well as boundaries shown on early Ordnance Survey mapping. The magnetometer survey proved less able to distinguish the earthworks or other modern features/activity due to the presence of superficial drift deposits of alluvium to the north of the site and boulder clay over the remainder.

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Report Information

Client:	English Heritage
Address:	English Heritage, Centre for Archaeology, Fort Cumberland, Fort Cumberland Road, Eastney, Portsmouth, Hampshire, PO4 9LD
Report Type:	Geophysical survey
Location:	Byland Abbey
County:	North Yorkshire
Grid Reference:	SE 5490 7900
Period(s) of activity represented:	
Report Number:	1941
Project Number:	3400
Site Code:	BYA09
Museum Accession No.:	n/a
Date of fieldwork:	March 2009
Date of report:	April 2009
Project Management:	Alistair Webb BA MIfA Sam Harrison BSc MSc AIfA
Fieldwork:	Alex Harrison BSc Sam Harrison BSc MSc AIfA Emma Watson BSc PG Dip Ian Wilkins BSc MSc
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Authorisation for distribution: --

ISOQAR ISO 9001:2000
Certificate No. 125/93

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1 Introduction

Archaeological Services WYAS was commissioned by Louise Martin of English Heritage to carry out a program of non-intrusive geophysical survey (magnetometer and earth resistance survey) over part of the former precinct of Byland Abbey. The total area covered by both surveys was approximately 7.5 hectares.

Site location, topography and land use (see Figs 1 and 2)

Byland Abbey (Scheduled Monument Number 13279) is situated on the southern edge of North York Moors National Park at SE 5490 7900 (see Fig. 1) approximately 25km south-east of Northallerton. A Section 42 Licence was obtained prior to the survey (see Appendix 5).

Four areas to the west and north-west of the abbey, were surveyed (see Fig. 2). Area A was situated to the north-west of the abbey and south-west of Abbey House. Areas B and C were located directly south of College Farm and west and south-west of the abbey respectively and Area D was to the north of Mowbray House. Areas A, B and C were under permanent pasture whilst Area D formed the garden of Mowbray House.

Areas A and D were relatively flat whilst Areas B and C have steep banks and scarps. Located within all areas were numerous earthworks recently mapped by English Heritage (see Fig. 5).

Geology and soils

The solid geology of the site is the Cloughton Formation of the Ravenscar Group, part of the Middle Jurassic Bajocian groups. This is overlain by superficial deposits of alluvium in Area A and boulder clay over the remainder of the site (BGS 1992, 1992b).

The soils in Areas B, C and D are classified in the Dunkeswick association comprising slowly permeable seasonally waterlogged fine loams and fine loams over clay. In Area A the soils are classified in the Dale association comprising slowly permeable waterlogged clays, often stoneless (SSEW 1983).

2 Archaeological background

Byland Abbey was settled by a community of Cistercian monks in 1177 and occupied until the Dissolution in 1539. The plan is typically Cistercian but the other features within the wider precinct are only poorly understood. Previous studies have suggested that much of the precinct was taken up with water management with various watercourses and ponds.

Recent investigations by English Heritage have suggested that the area under water was probably much less than had been previously been thought and some earthworks may in fact relate to post-Dissolution use of the site. This survey has also identified features within fields that would seem to be buildings, wall lines, close boundaries, former leats and natural water courses.

A previous geophysical survey was undertaken in the immediate vicinity of the abbey cloister and the Abbey Inn garden where numerous structural remains were located (English Heritage 2009).

The fist edition Ordnance Survey mapping (see Fig. 6) of the area, produced in 1856 identifies a number of field boundaries, tracks and structures no longer extant.

3 Aims, Methodology and Presentation

The general aim of the fieldwork was to obtain information that would enhance the archaeological features of the recent earthwork survey of the abbey precinct.

Specifically the aims were:

- To determine (so far as is possible) the presence or absence of buried archaeological remains in the survey area
- To clarify the extent and layout of known sites of archaeological interest within or adjacent to the study area
- To clarify the extent and layout of previously unknown buried remains within the survey area
- To interpret any geophysical anomalies identified by the survey.

These aims were to be achieved by undertaking detailed (recorded) magnetometer and earth resistance survey at four pre-determined locations.

Area A (4.1 hectares) was situated to the north-west of the Abbey, to the north of College Farm and the Abbey Inn and south-east of Abbey House. Area B (1.72 hectares) is south-west of College Farm with Area C (1.96 hectares) directly to the south of Area B. The garden of Mowbray House encompassed Area D (0.25 hectares).

The survey grids were set out using a Trimble 5800 dGPS system using a reference object sited by English Heritage during the earthwork survey. The grids were then superimposed onto a digital Ordnance Survey map base supplied by the client.

Magnetometer survey

Bartington Grad601 magnetic gradiometers were used during the survey taking readings at 0.25m intervals on zig-zag traverses 1m apart within 30m by 30m grids so that 3600 readings were recorded in each grid. These readings were stored in the memory of the instrument and later downloaded to computer for processing and interpretation. Geoplot 3 (Geoscan

Research) software was used to process and present the data. Further details are given in Appendix 1. At the request of the client the survey was traversed north/south.

Earth resistance survey

A Geoscan RM15 resistance meter was used during the earth resistance survey, with the instrument logging each reading automatically at 1m intervals on traverses 1m apart. The mobile probe spacing was 0.5m with the remote probes 15m apart and at least 15m away from the grid under survey. This mobile probe spacing of 0.5m gives an approximate depth penetration of 1m for most archaeological features.

Reporting

A general site location plan, incorporating the 1:50000 Ordnance Survey mapping is shown in Figure 1 with a more detailed plan showing the survey areas presented in Figure 2. Figures 3 and 4 show the magnetometer and earth resistance data at a scale of 1:2000. The earthwork survey undertaken by English Heritage is shown in Figure 5 also at 1:2000. Figures 6a and 6b shows the first edition Ordnance Survey mapping of 1856 overlain with the magnetic and resistance data respectively. A relief plot of the earth resistance data is shown in Figure 7. The processed greyscale data, the 'raw' XY trace plot data and interpretation figures for the magnetometer and earth resistance data are presented for each area at a scale of 1:1000 in Figures 8 to 31 inclusive. To aid understanding of the results the interpretations for each area are shown with and without the earthwork survey overlaid.

Further technical information on the equipment used, data processing and survey methodologies are given in Appendix 1, Appendix 2 and Appendix 3. Appendix 4 describes the composition and location of the archive.

The survey methodology, report and any recommendations comply with the Specifications (English Heritage 2009) and guidelines outlined by English Heritage (David *et al* 2008) and by the IfA (Gaffney, Gater and Ovenden 2002). All figures reproduced from Ordnance Survey mapping are with the permission of the controller of Her Majesty's Stationery Office (© Crown copyright).

The figures in this report have been produced following analysis of the data in 'raw' and processed formats and over a range of different display levels. All figures are presented to most suitably display and interpret the data from this site based on the experience and knowledge of Archaeological Services staff.

4 Results

Magnetometer Survey

Area A (Figs 8, 9 and 10a/b)

The most obvious aspect of the magnetic data is how little obvious correlation there is between the magnetic anomalies and the earthworks. The most clear cut comparison is opposite the gatehouse where a very well defined rectilinear area of enhanced responses (**A**) matches the mapped earthworks. The magnetic responses are considered likely to be due to demolition rubble.

One hundred metres to the east, immediately south of the stream, another cluster of anomalies (**B**) has been highlighted, some of which exhibit a degree of linearity. One or two of these anomalies broadly correspond to the complex of linear and rectilinear earthworks mapped in this part of the site.

To the north of the stream in the main part of Area A there is very little correspondence. A series of broad, low magnitude linear areas of enhanced magnetic response dominates the data across the central part of the area. The largest anomalies to the south trend broadly south-east/north-west, at 45° to most of the earthworks. To the east and north-west the anomalies are less coherent and fragmentary, again with no correlation to the series of enclosures mapped here. The broad nature and low magnitude of these anomalies suggests a natural, geological, origin.

In contrast to these low magnitude anomalies are five clusters of a fairly ‘spiky’ responses (Fig. 10 – **C**). Again there is no obvious correlation to the earthworks but they have been interpreted as potentially archaeological.

To the north of the area the magnetic background is much flatter with no geological anomalies. Three low broad anomalies have been interpreted as potentially archaeological as they broadly match with the position of a trackway and bridging point shown on the first edition Ordnance Survey map (see Fig. 6b). The line of a field boundary can just be discerned aligned north-west/south-east against this flat background. Another very weak anomaly on the same alignment has also been tentatively identified.

A service pipe has been traced running north-east/south-west immediately north of the stream and around the eastern edge of the survey area.

Area B (Figs 11, 12 and 13a/b)

This area is split into two by the track to College Farm. To the north of the track the magnetic background is very ‘quiet’ except to the eastern apex of the triangular land parcel. Here a cluster of enhanced responses correlates with a series of intersecting earthworks. West of these earthworks ridge and furrow earthworks have been mapped in the recent earthwork survey but they are not evident as magnetic anomalies.

To the south the earthworks are just discernible as very weak, vague linear trends accentuated by aggregations of discrete anomalies. One small cluster of anomalies to the immediate west of the possible dam is notable as it does not correlate with any earthworks.

Area C (Figs 14, 15 and 16a/b)

The major linear earthwork is partially visible as a weak, broad, magnetic anomaly (**E**). Immediately to the south of it is a small cluster of responses that correspond with three small sub-circular earthworks. Twenty metres to the south is another cluster of magnetic responses that again partially correlates with earthworks.

To the north-west corner another low magnitude broad area of enhancement corresponds with another small sub-circular earthwork. A line of weak, intermittent responses aligned north/south locates the line of a former field boundary (see Fig. 6), also visible as earthworks.

Perpendicular to the southern boundary of the survey area are a series of strong, parallel linear anomalies, aligned south-west/north-east that are caused by ridge and furrow ploughing which terminate just short of a linear earthwork.

A ferrous pipe crosses the area from south to north towards the eastern side if the area

Area D (Figs 17, 18 and 19a/b)

The response from a ferrous pipe masks any potential archaeological responses to the western half of the garden area. To the east a cluster of enhanced magnetic responses locates the demolished remains of a structure shown on the first edition Ordnance Survey mapping.

Earth Resistance Survey

Area A (Figs 20, 21 and 22a/b)

The earth resistance survey generally exhibits a good correlation with the earthwork survey in this area identifying high resistance anomalies across much of the area (see anomalies **F** – **L**), although a number of earthworks did not manifest as resistance anomalies. In addition a number of possible extensions to recorded earthworks have been noted (see anomalies **G**, **K** and **N**) as high resistance anomalies. Broad areas of low resistance reflect the relatively high moisture retention in areas adjacent to the major high resistance anomalies such as **J** and **L**, often in slight depressions.

Anomaly **J**, running around the eastern periphery of the area, exhibits the highest resistance of any of the anomalies. Given the strength of this anomaly it is thought that it is probably caused by a compacted earthen pathway leading to the small bridge that is still present near the southern edge of this area.

High resistance anomalies **F** and **L** have been identified as possible structures. Anomaly **F** in the south-west of the area clearly corresponds with the earthwork covering an area of approximately 20m by 20m. Its position opposite with the gatehouse may suggest some associated function. Notably the first edition map also shows a separate boundary around this area (see Fig. 6).

At the southern apex of the area, south of the stream, a complex of short linear anomalies has been identified. Generally the trend of these various anomalies matches the earthworks except right at the southern end where a small sub-square anomaly **(L)** measuring approximately 10m by 10m, and not identified in the earthwork survey, is present. It is unclear as to the origin of this anomaly but it could be structural.

Parallel with the south-west boundary of this area are two linear, high resistance anomalies (**G**) which correspond with two boundaries, shown on the first edition map, that leads up to possible structure **F**. At the south-western corner a single anomaly (**H**) continues up the western boundary edge corresponding with an earthwork and previous field boundary.

A number of weaker high resistance anomalies have also been recorded in the data. The majority of these match earthworks with the exception of anomaly **N** which may be a continuation of a former watercourse (**O**) which does correspond with an earthwork.

Three high resistance linear trends (**P**) in the south-west of the area are of an unknown origin. They are not recorded in the earthwork survey or shown on the early mapping. It is possible that these anomalies are features such as stone lined drains.

A service pipe running north-east/south-west shows as a low resistance linear trend.

High resistance linear trend anomalies interpreted as field drains run in a general east-west direction in a typical herringbone pattern – they do not manifest as magnetic anomalies. Numerous linear trends have been recorded heading north-south in the earth resistance data. It is unclear if these anomalies are due to ploughing or striping caused by the use of a multiplexer system.

Area B (Figs 23, 24 and 25a/b)

The major linear and curvilinear earthworks in this area clearly show as high/low resistance anomalies notably **Q**, **R**, and **S**. To the north-eastern corner sub-rectangular high and low resistance anomalies, **T,** also broadly reflect the upstanding earthworks

A weak linear trend (**U**) aligned west/east may mark the continuation of a short linear high resistance anomaly in the north-eastern corner of the survey area.

To the north-west and along the southern edge parallel linear trends in the data are thought to reflect ploughing.

Area C (Figs 26, 27 and 28a/b)

The largest earthwork on the whole site is again prominent as a high resistance anomaly (**W**) running broadly parallel with the northern edge of the survey area. To the south of **W** several high resistance anomalies are identified particularly at the western end. Two clearly correlate with circular earthworks but others do not. Whether these anomalies (**V**) are indicative of archaeological features is not clear. Two other areas of high resistance (**Y**) further to the east similarly do not correlate with earthworks and have an unknown potential.

On the same broad alignment as **W,** towards the southern edge of the area is an intermittent high resistance anomaly (**X**) which locates a trackway situated on the edge of a natural ridge in the landscape.

At the western end, between these two linear anomalies, are parallel high and low resistance linear trends which reflect slight earthworks that also correlate with a field boundary on the first edition mapping.

A former field boundary has been identified in the west of the area with a small number of parallel linear trends thought to be agricultural in origin.

Area D (Figs 29, 30 and 31a/b)

A low resistance anomaly aligned north/south is due to a pipe trench..

Areas of high resistance (Z) at the eastern end of the garden a probably due to the demolished remains of a building shown on the first edition Ordnance survey mapping (see Fig. 6).

5 Discussion and Conclusions

Due to the long history of the site, mirrored by the complexity of the earthworks, it has been difficult to confidently interpret the origin of many of the anomalies other than to say that they reflect the mapped earthworks to differing degrees in each of the survey areas. Many of the smaller areas of high and low resistance not obviously due to earthworks have not been specifically described in the text but have been interpreted as potentially archaeological on the basis of the obvious huge potential of the whole area under survey. However, it is considered equally likely that some of these anomalies are simply due to the differential compaction of, and water retention within, the natural deposits.

The most difficult area in which to interpret the magnetic data has been in Area A where the effect of the alluvium on the data has masked any potential archaeological responses across the majority of the area. The resistance data from this area is considerably easier to interpret with all the major earthworks clearly visible, especially prominent being the longitudinal earthwork (**I**) which runs north/south splitting the area in half, which appears to continue all the way to the northern edge of the site and the east/west aligned earthwork (**M**). Trackways around the eastern and western periphery of the area are also extremely well defined. These boundaries/trackways are however, shown on the first edition mapping.

Both techniques have clearly defined probable structures, opposite the gatehouse and to the south of the stream but here again neither technique has added any significant detail to that already provided by the earthwork survey. Another structure has been located at the eastern end of the garden in Area D by both techniques but this is also shown on the first edition mapping.

Both techniques located the modern ferrous pipe that runs south-west/north-east but only the resistance survey has picked up what is presumed to be a series of land drains.

Neither survey has identified any anomalies that can definitely be interpreted as archaeological with the vast majority of anomalies either obviously due to upstanding earthworks or to features shown on the first edition Ordnance Survey mapping. However, some anomalies have been identified by both techniques that do not correspond with either earthworks or former boundary features. Whilst none of these anomalies on any other site about which little was known might be interpreted as archaeological the obvious huge potential of this site means that an archaeological cause for any anomaly other than those due to modern pipes and drainage features cannot be dismissed.

The results and subsequent interpretation of data from geophysical surveys should not be treated as an absolute representation of the underlying archaeological and non-archaeological remains. Confirmation of the presence or absence of archaeological remains can only be achieved by direct investigation of sub-surface deposits.

Fig. 1. Site location

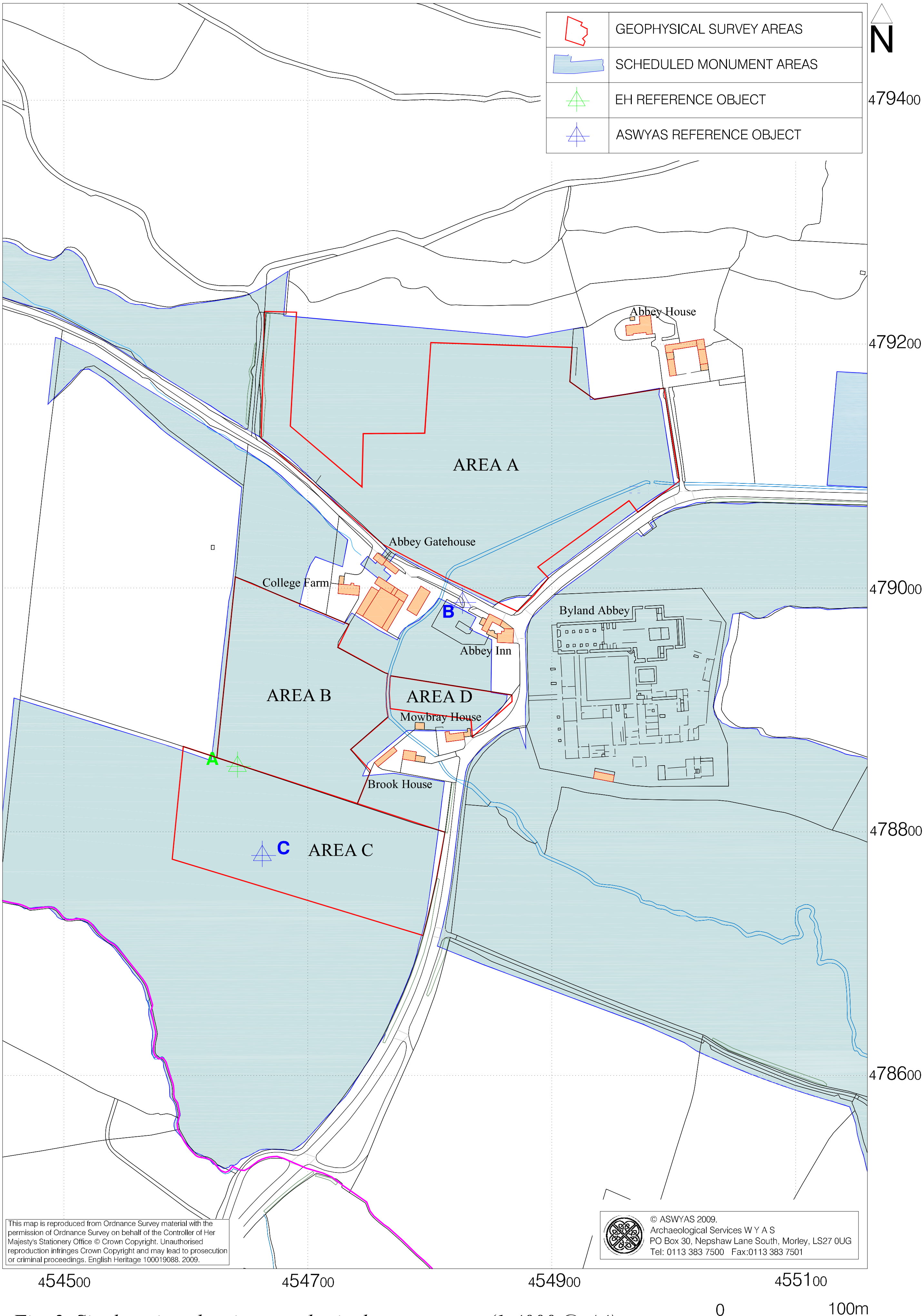

Fig. 2. Site location showing geophysical survey areas (1:4000 @ A4)

Fig. 3. Greyscale magnetometer data (1:2000 @ A3)

Fig. 4. Greyscale earth resistance data (1:2000 @ A3)

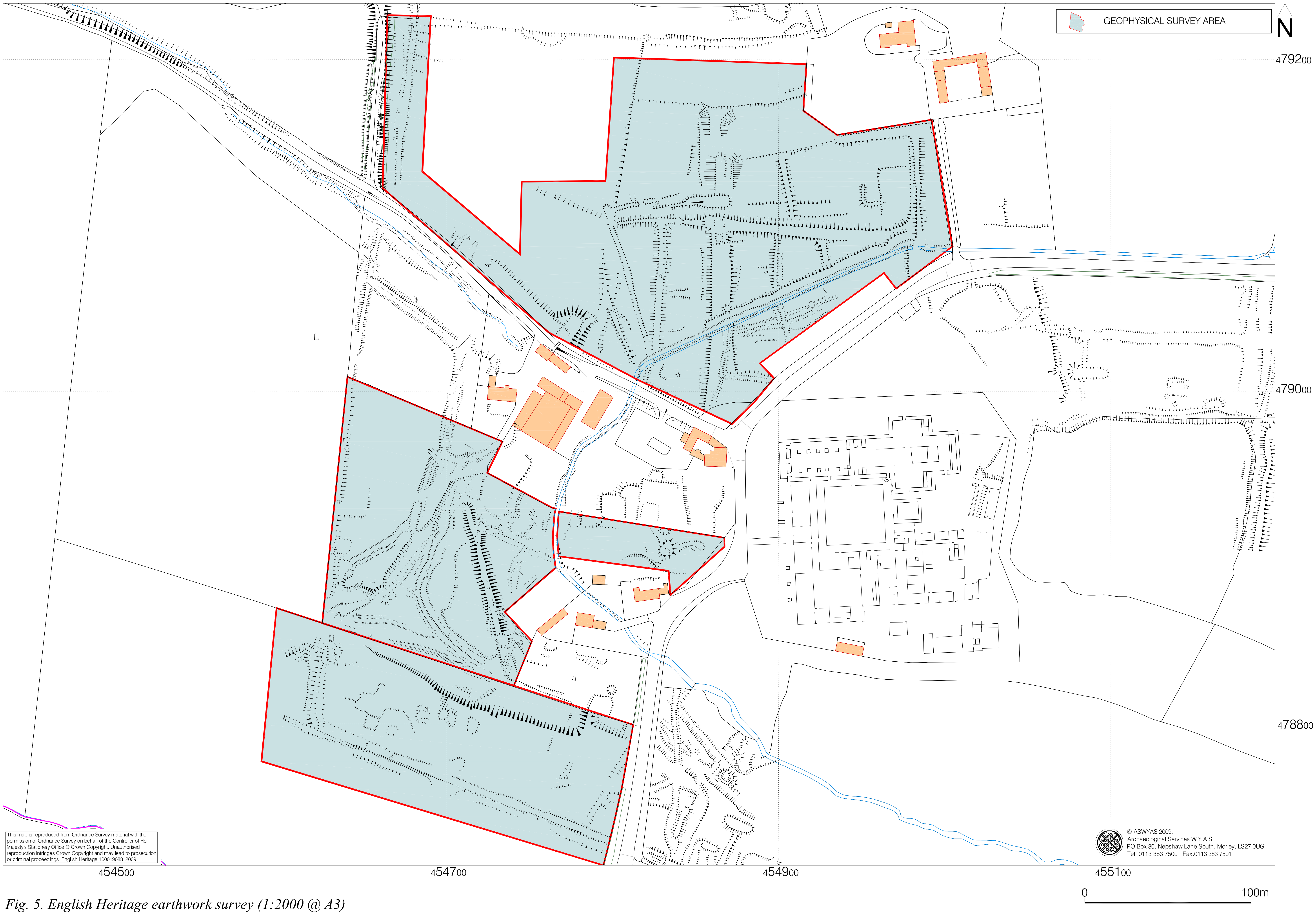

Fig. 5. English Heritage earthwork survey (1:2000 @ A3)

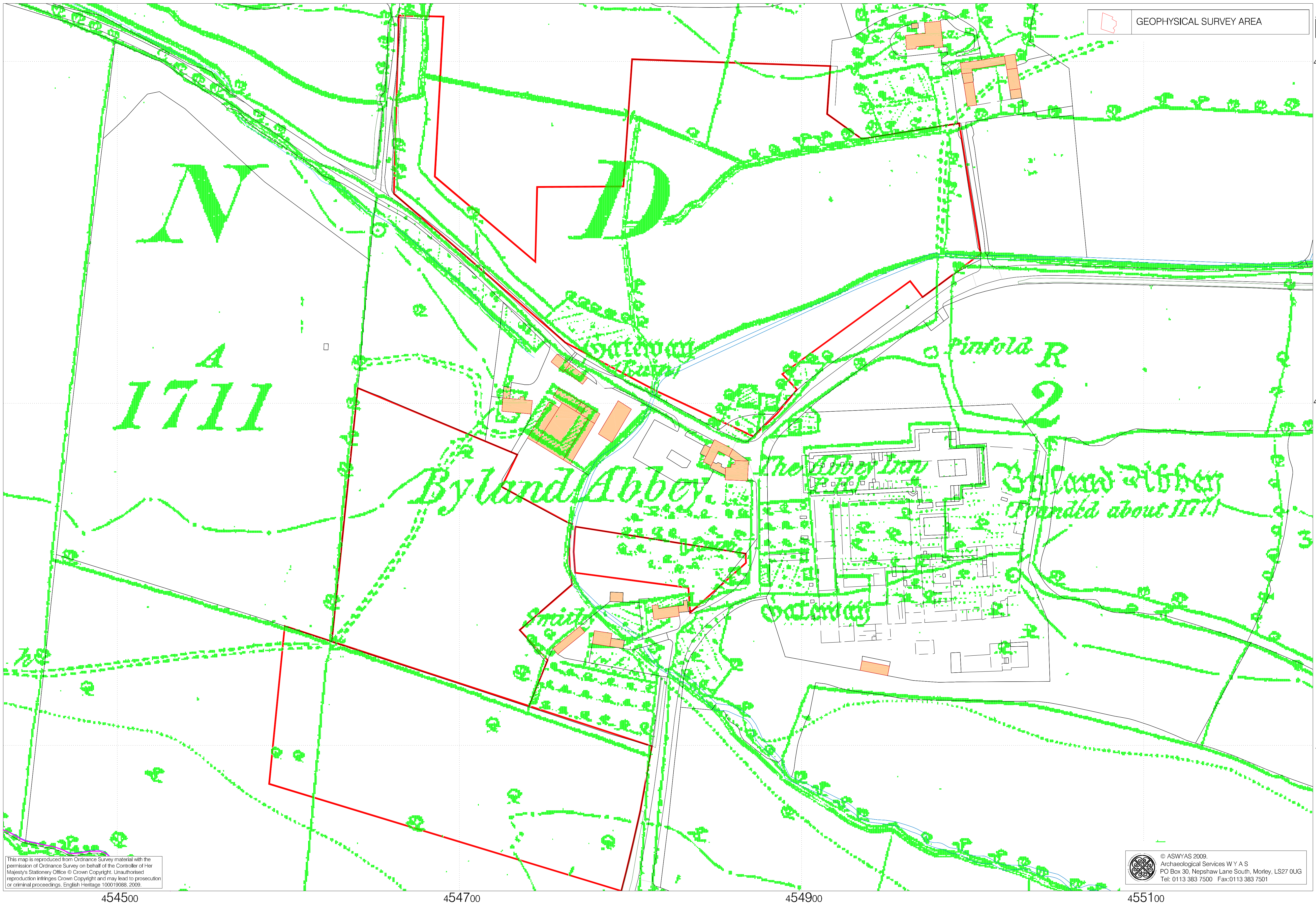

Fig. 6. First edition Ordnance Survey mapping of 1856 showing survey areas (1:2000 @ A3)

Fig. 7. Relief plot of earth resistance data (1:2000 @ A3)

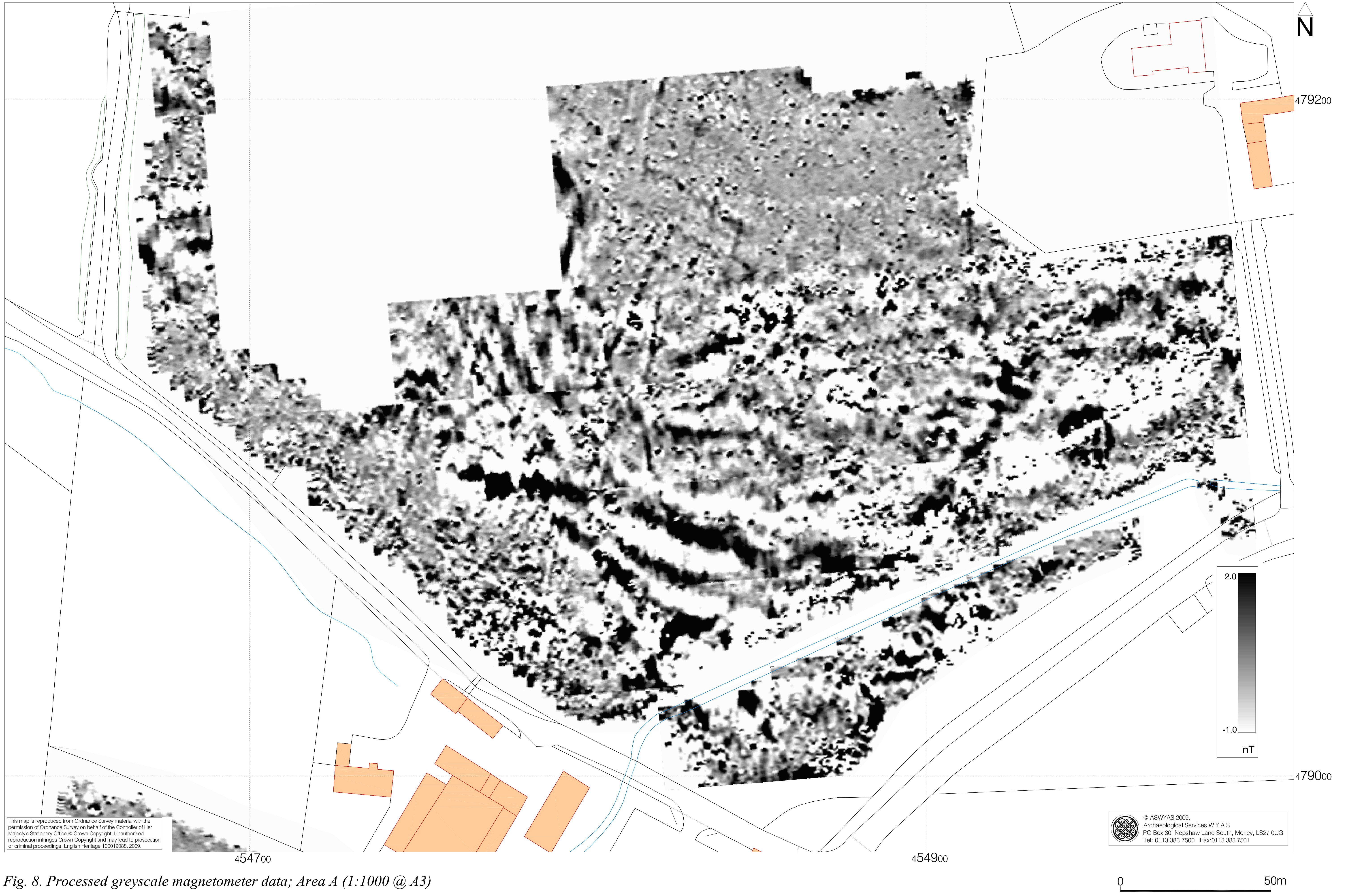

Fig. 8. Processed greyscale magnetometer data; Area A (1:1000 @ A3)

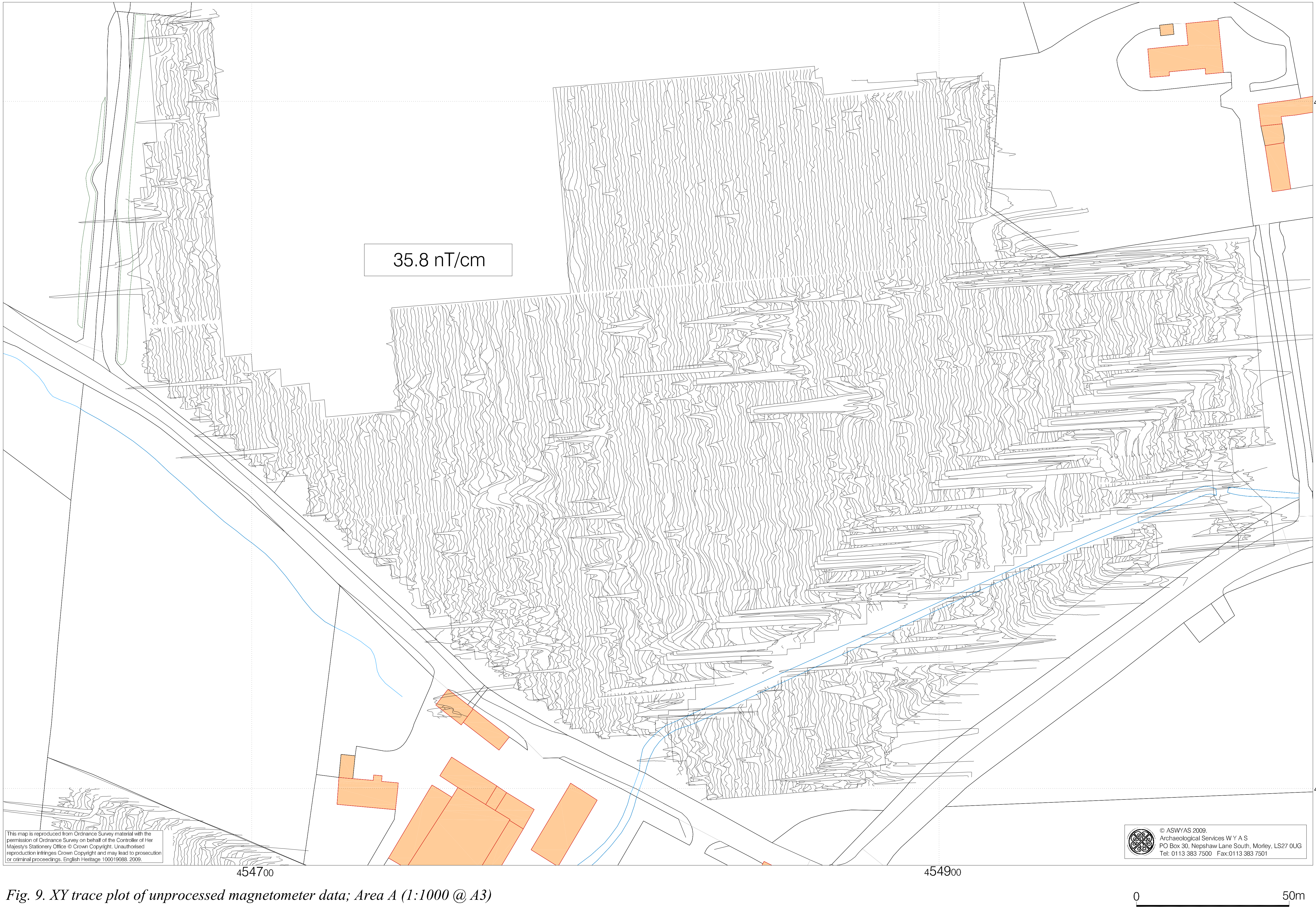

Fig. 9. XY trace plot of unprocessed magnetometer data; Area A (1:1000 @ A3)

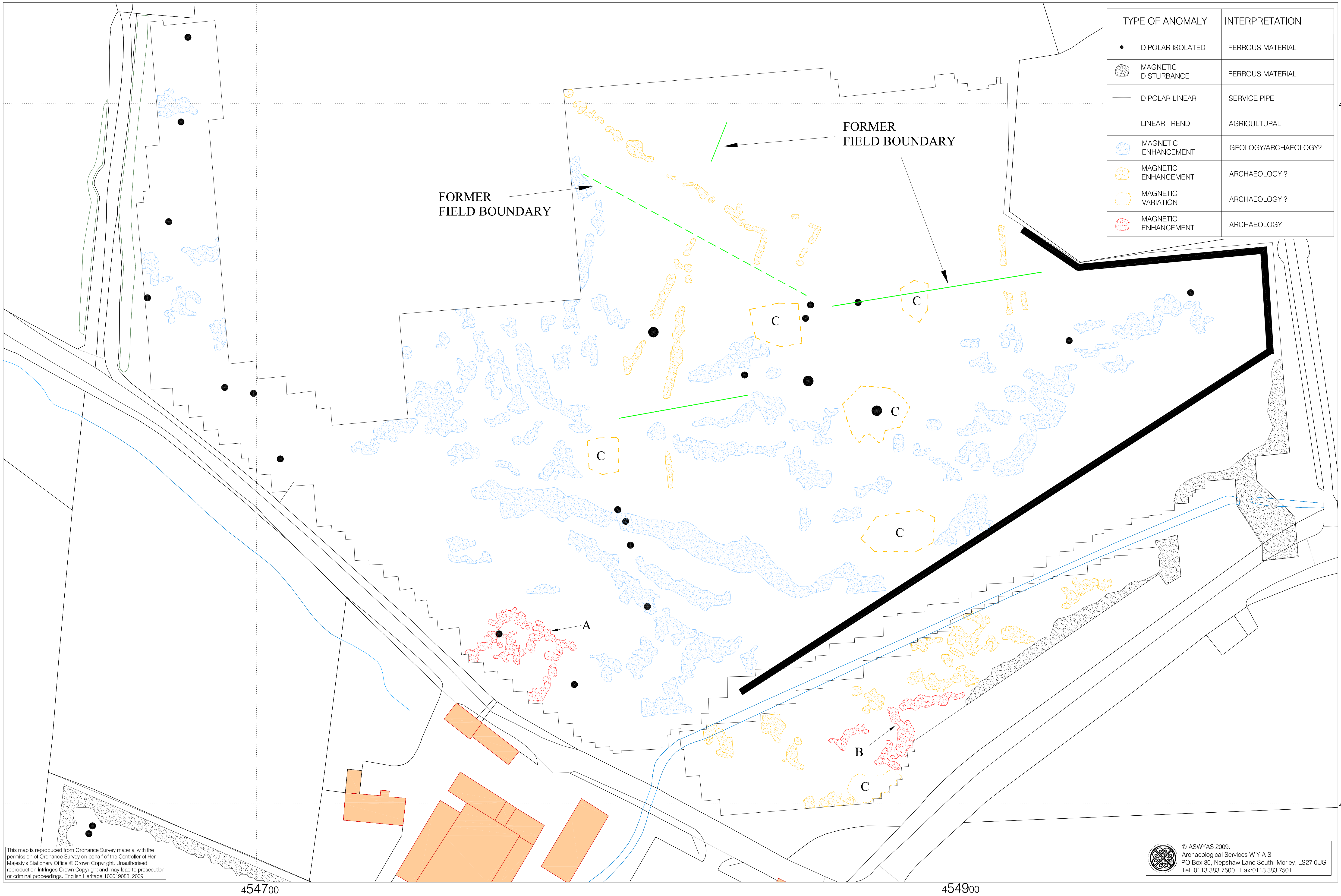

Fig. 10a. Interpretation of magnetometer data; Area A (1:1000 @ A3)

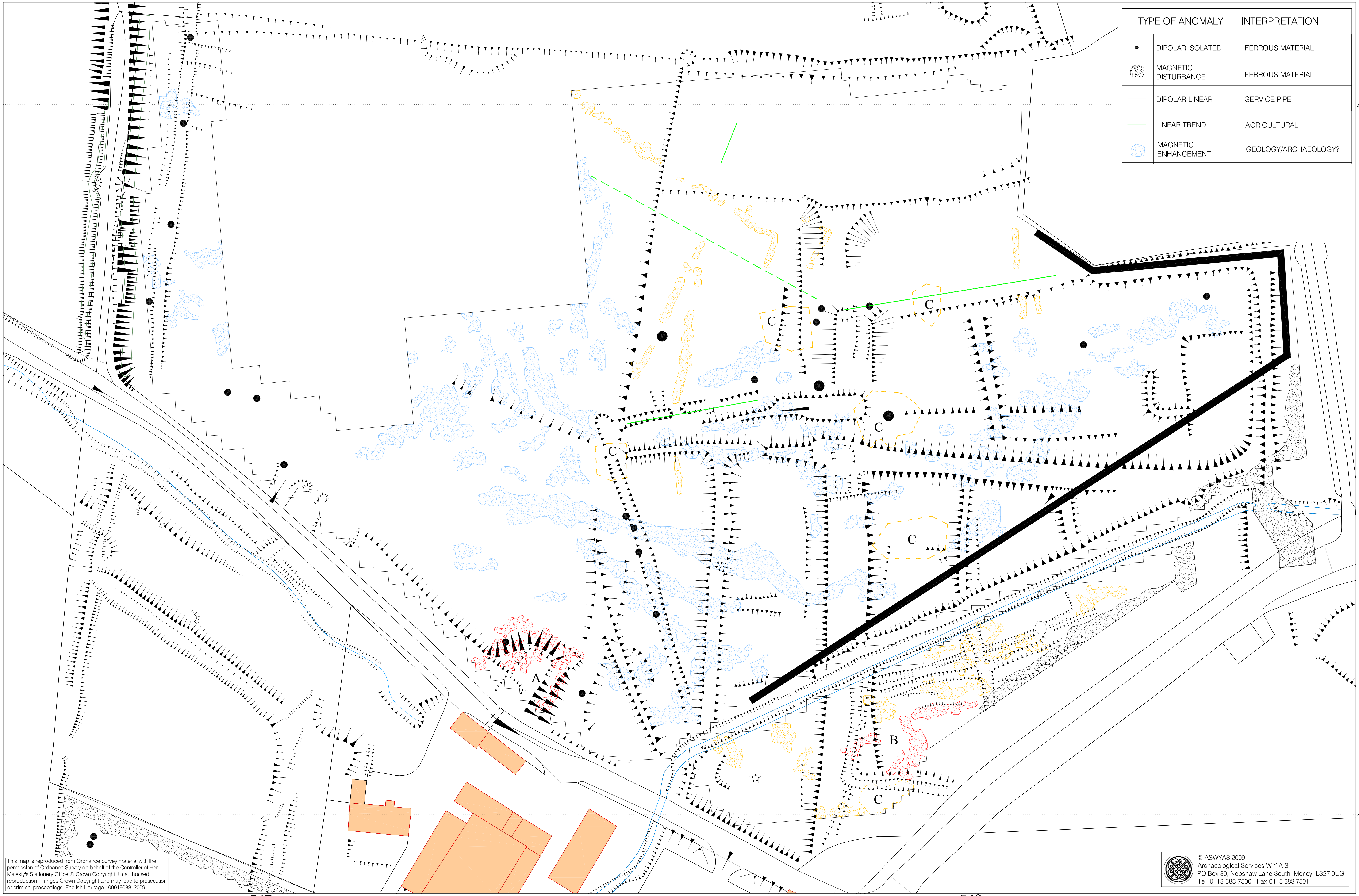

Fig. 10b. Interpretation of magnetometer data and hachured earthwork plan; Area A (1:1000 @ A3)

Fig. 11. Processed greyscale magnetometer data; Area B (1:1000 @ A4)

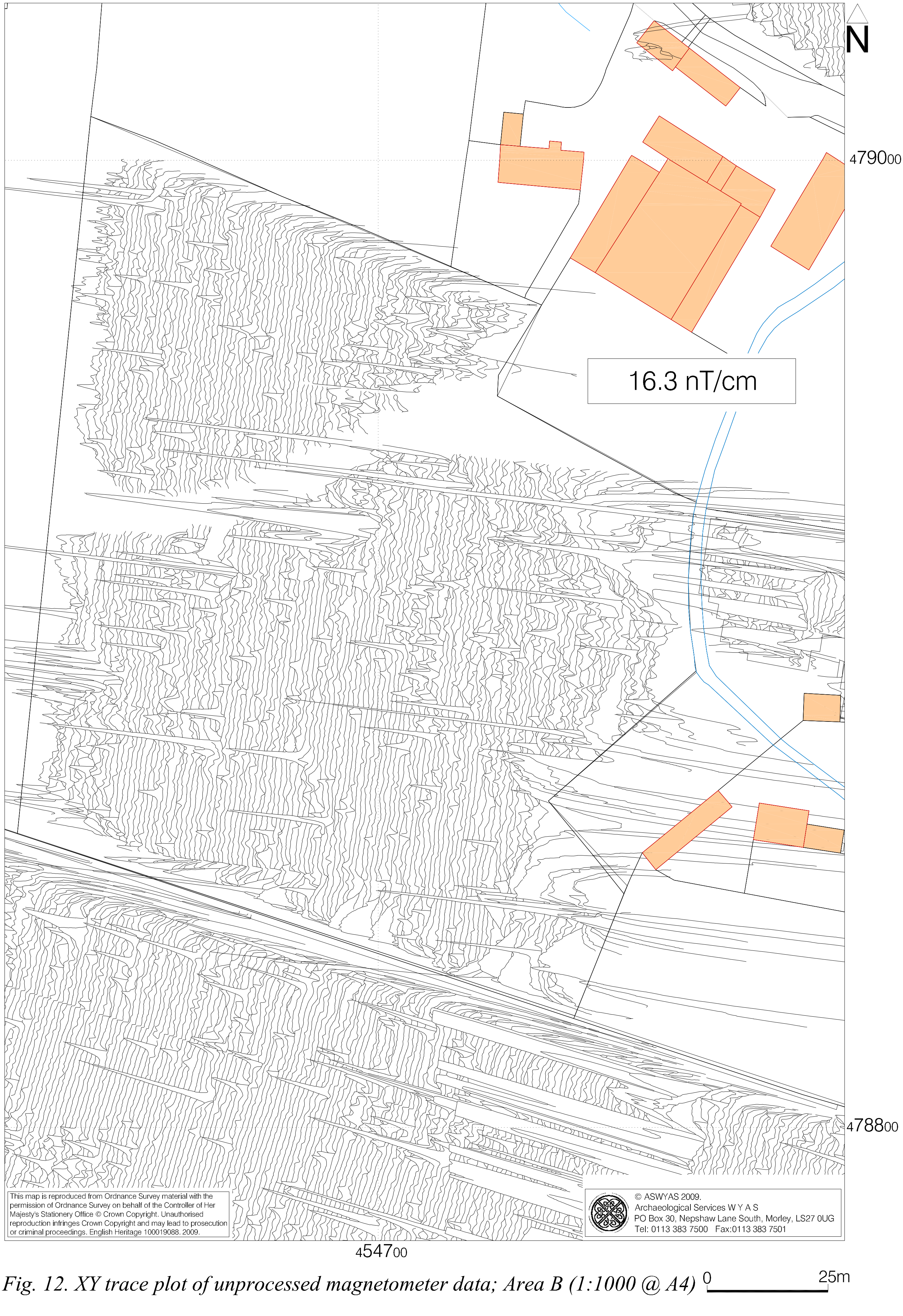

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Fig. 12. XY trace plot of unprocessed magnetometer data; Area B (1:1000 @ A4)

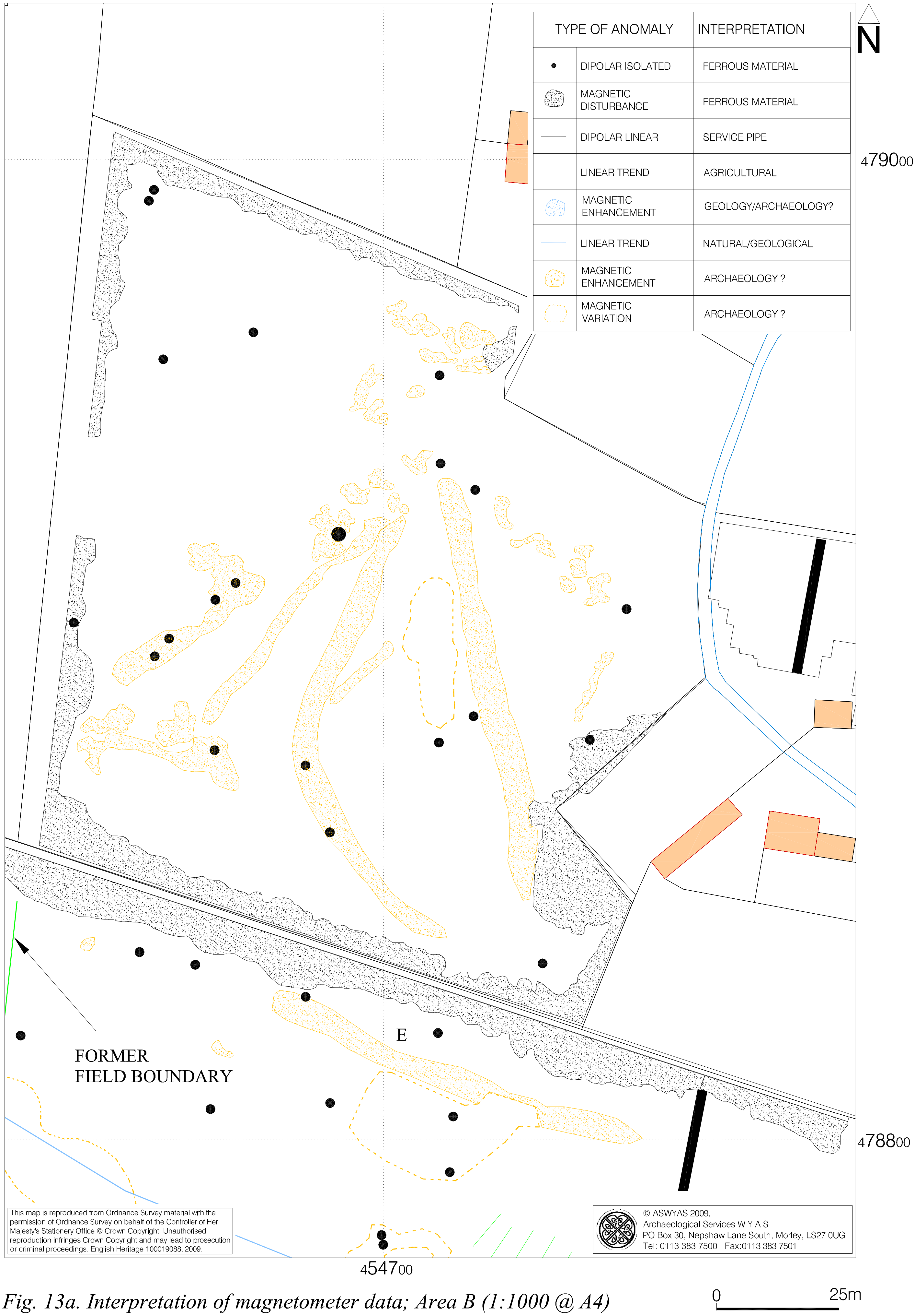

Fig. 13a. Interpretation of magnetometer data; Area B (1:1000 @ A4)

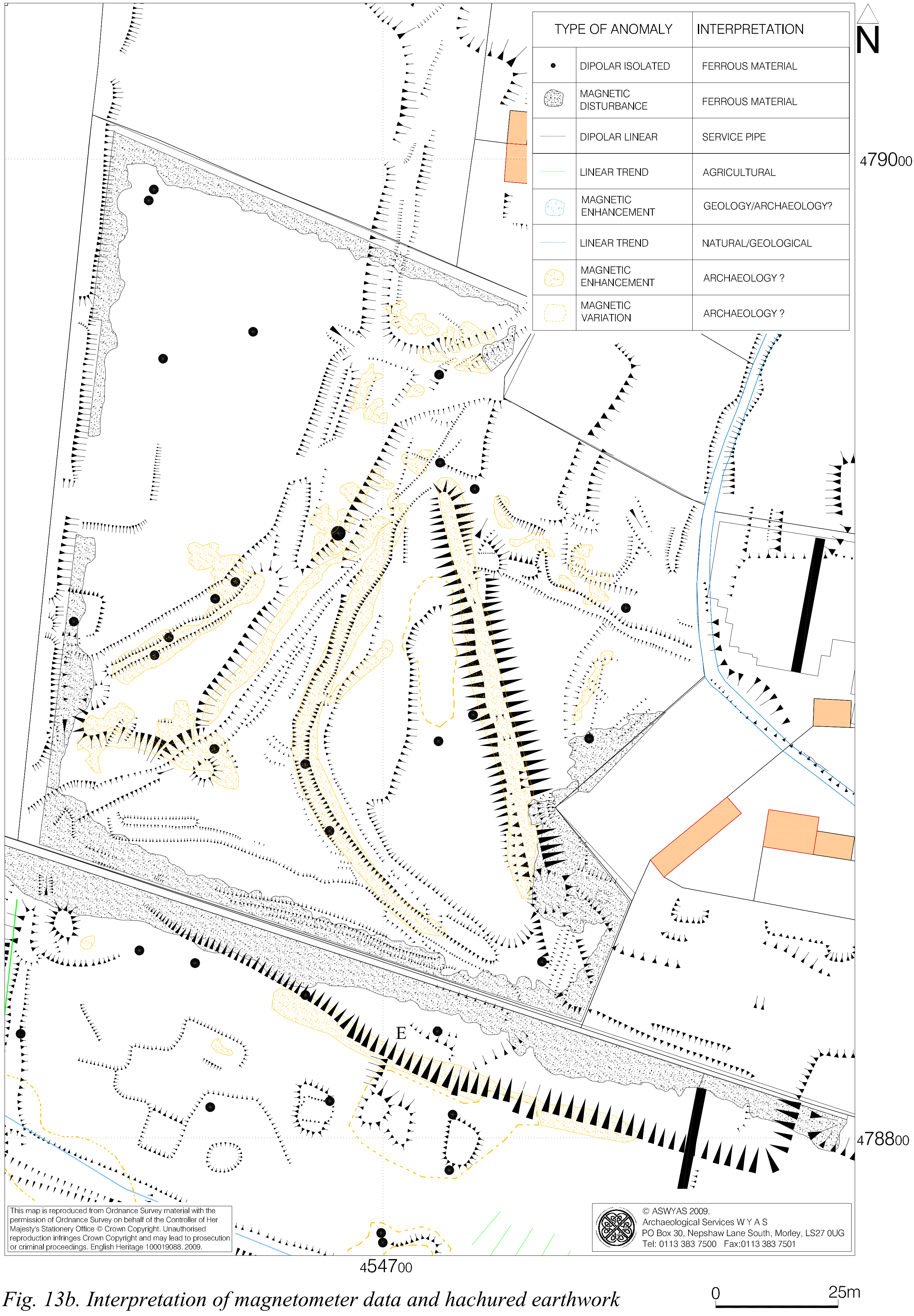

Fig. 13b. Interpretation of magnetometer data and hachured earthwork plan; Area B (1:1000 @ A4)

Fig. 14. Processed greyscale magnetometer data; Area C (1:1000 @ A4)

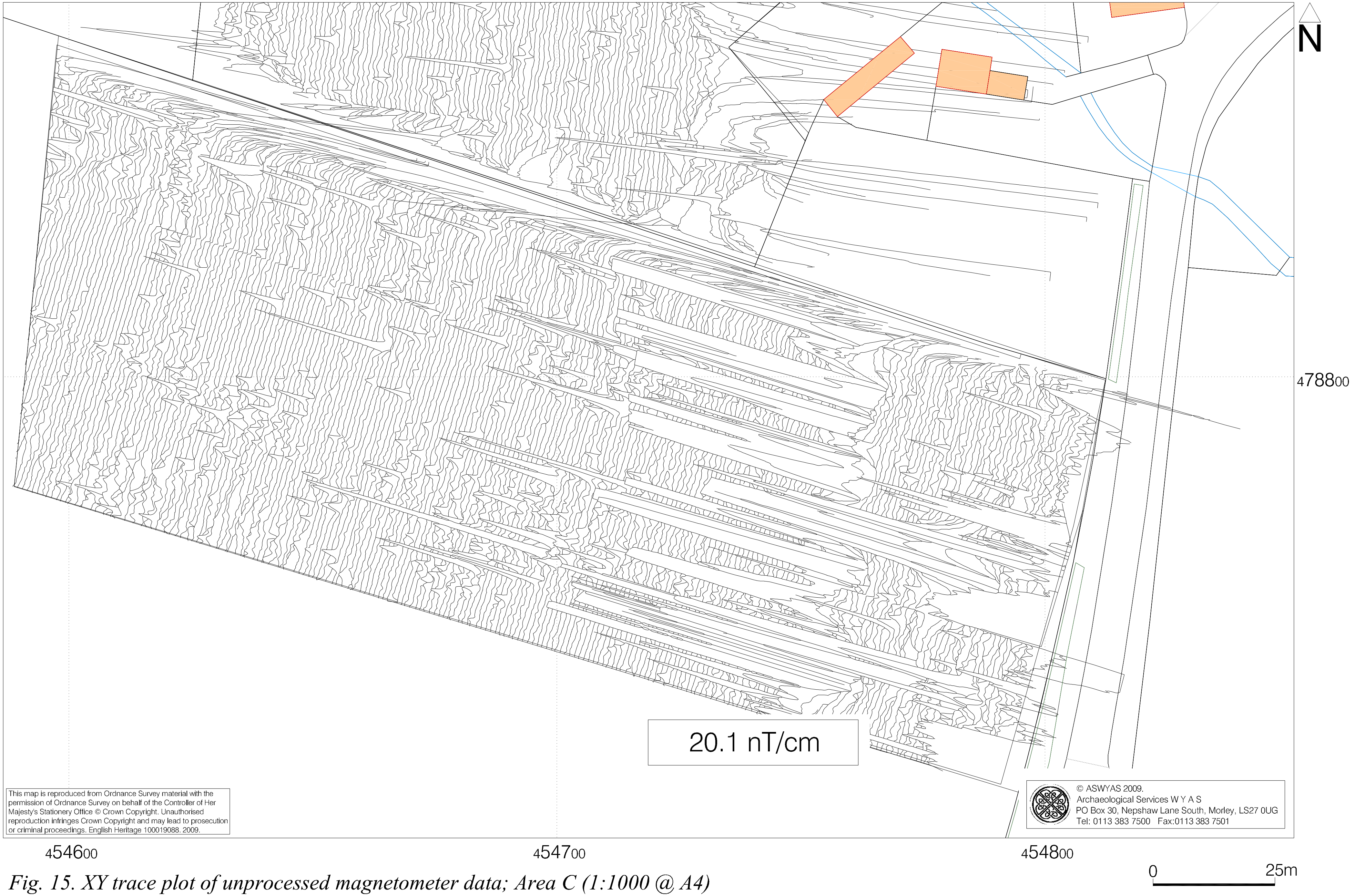

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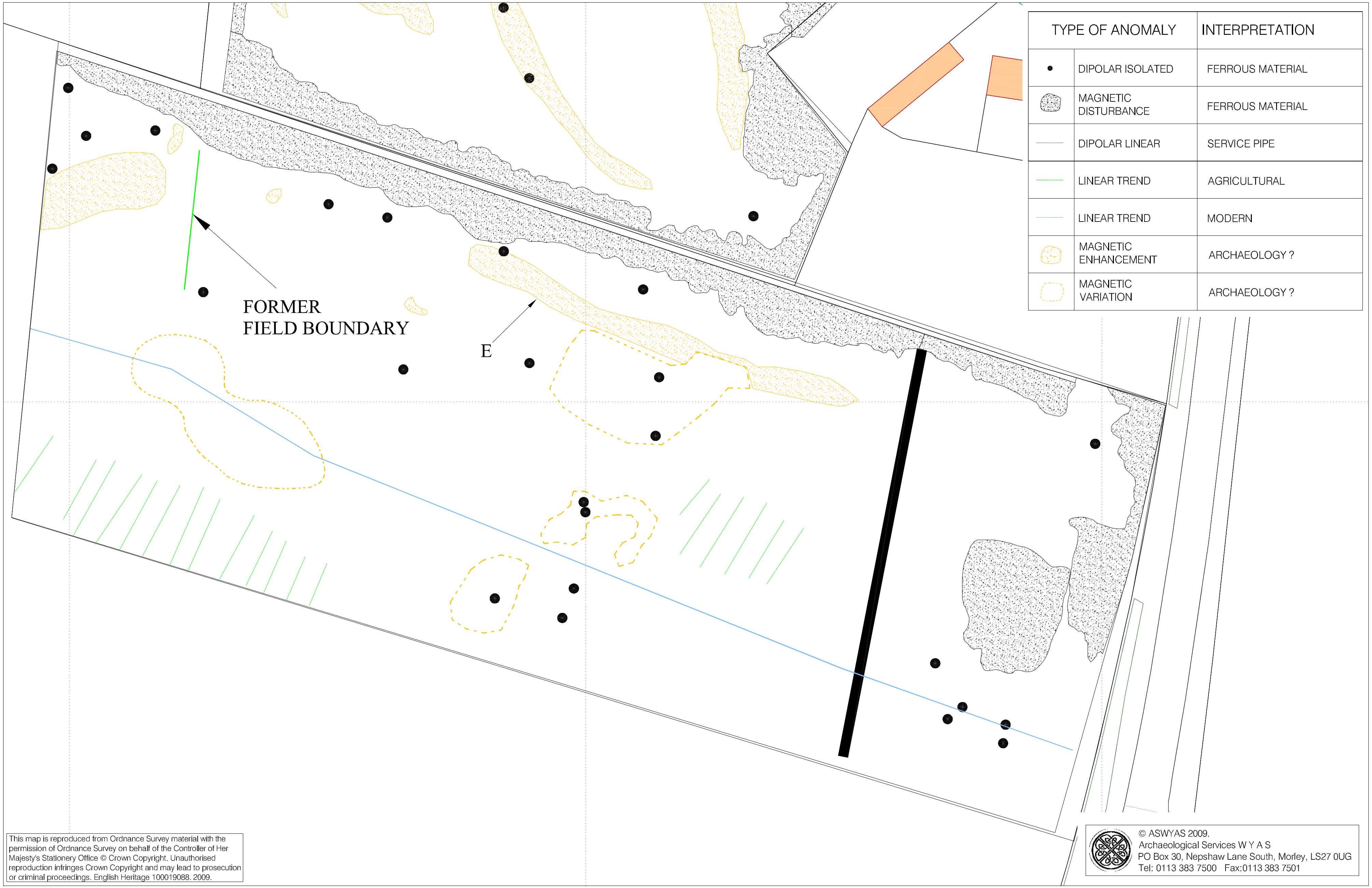
Fig. 15. XY trace plot of unprocessed magnetometer data; Area C (1:1000 @ A4)



TYPE OF ANOMALY		INTERPRETATION
	DIPOLAR ISOLATED	FERROUS MATERIAL
	MAGNETIC DISTURBANCE	FERROUS MATERIAL
	DIPOLAR LINEAR	SERVICE PIPE
	LINEAR TREND	AGRICULTURAL
	LINEAR TREND	MODERN
	MAGNETIC ENHANCEMENT	ARCHAEOLOGY ?
	MAGNETIC VARIATION	ARCHAEOLOGY ?

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Fig. 16a. Interpretation of magnetometer data; Area C (1:1000 @ A4)

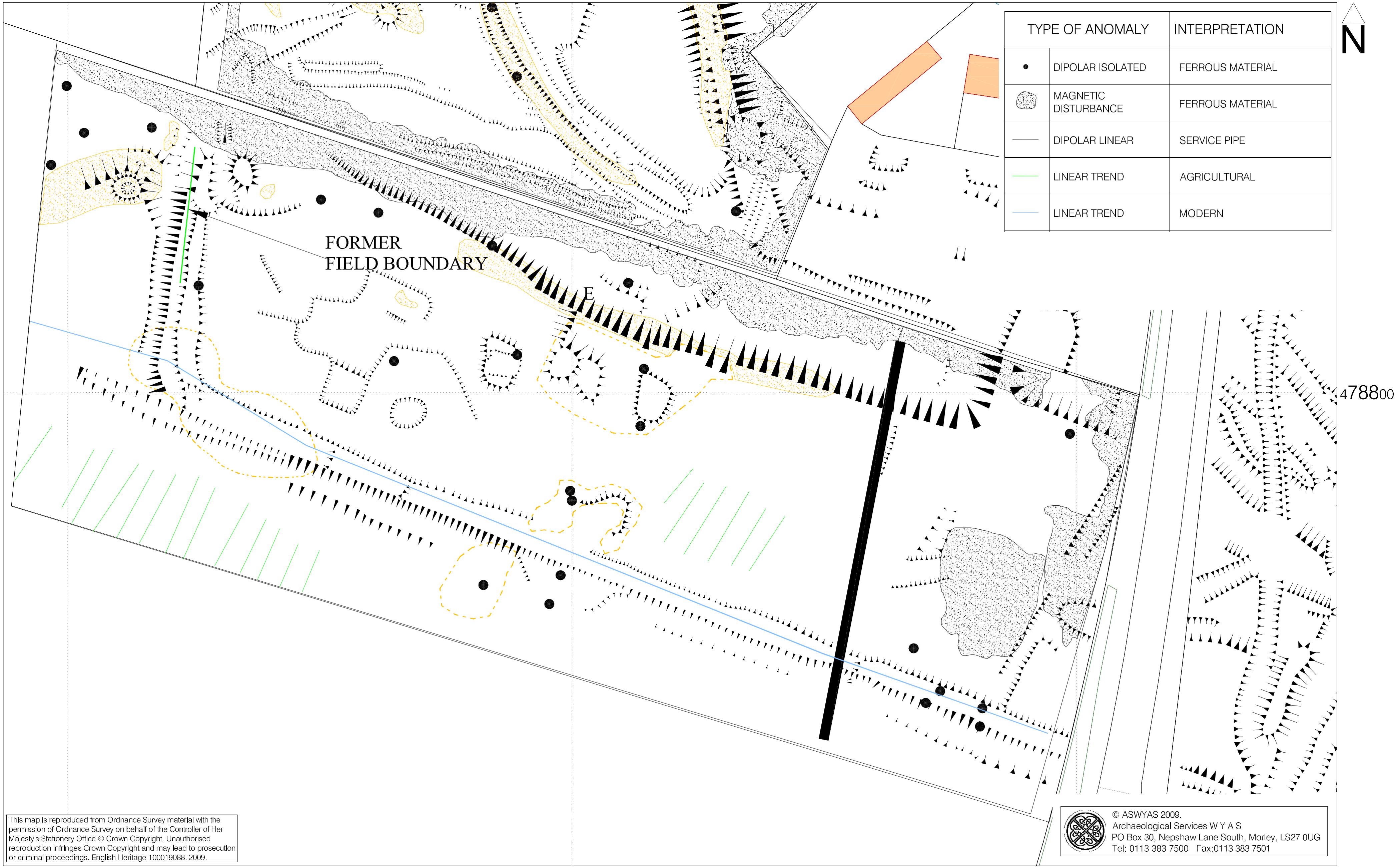

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Fig. 16b. Interpretation of magnetometer data and hachured earthwork plan; Area C (1:1000 @ A4)

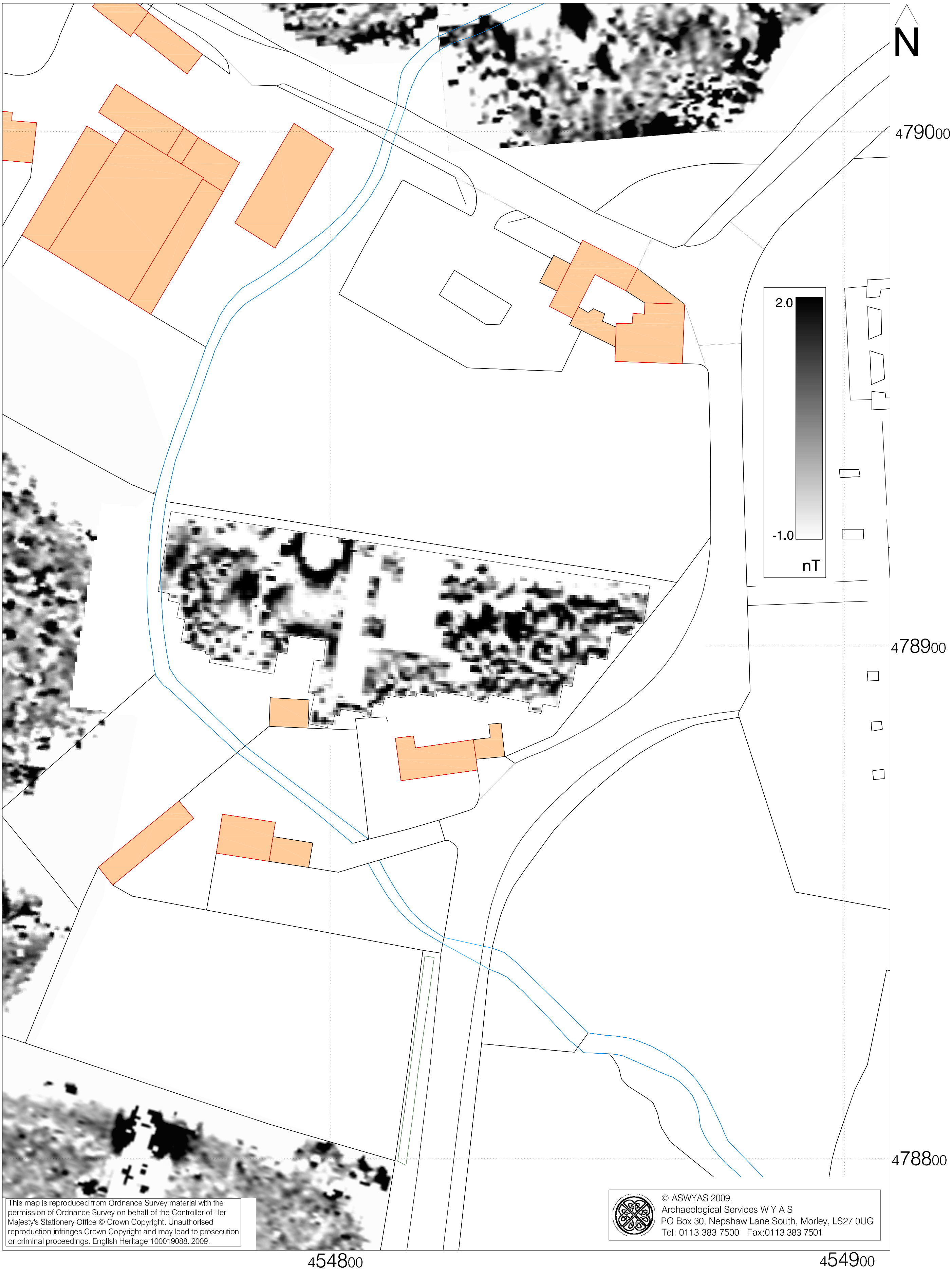

Fig. 17. Processed greyscale magnetometer data; Area D (1:1000 @ A4)

0 25m

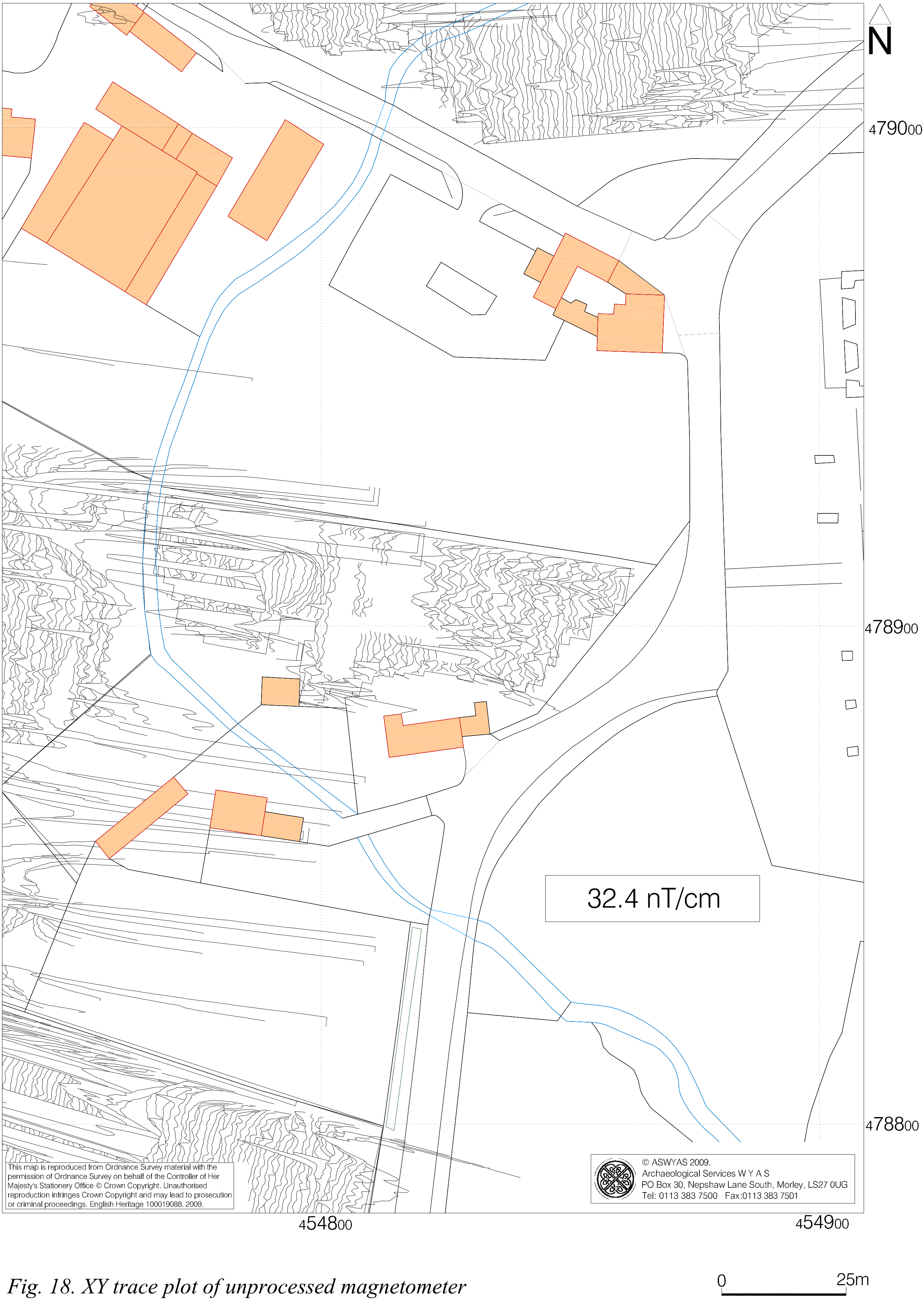

Fig. 18. XY trace plot of unprocessed magnetometer data; Area D (1:1000 @ A4)

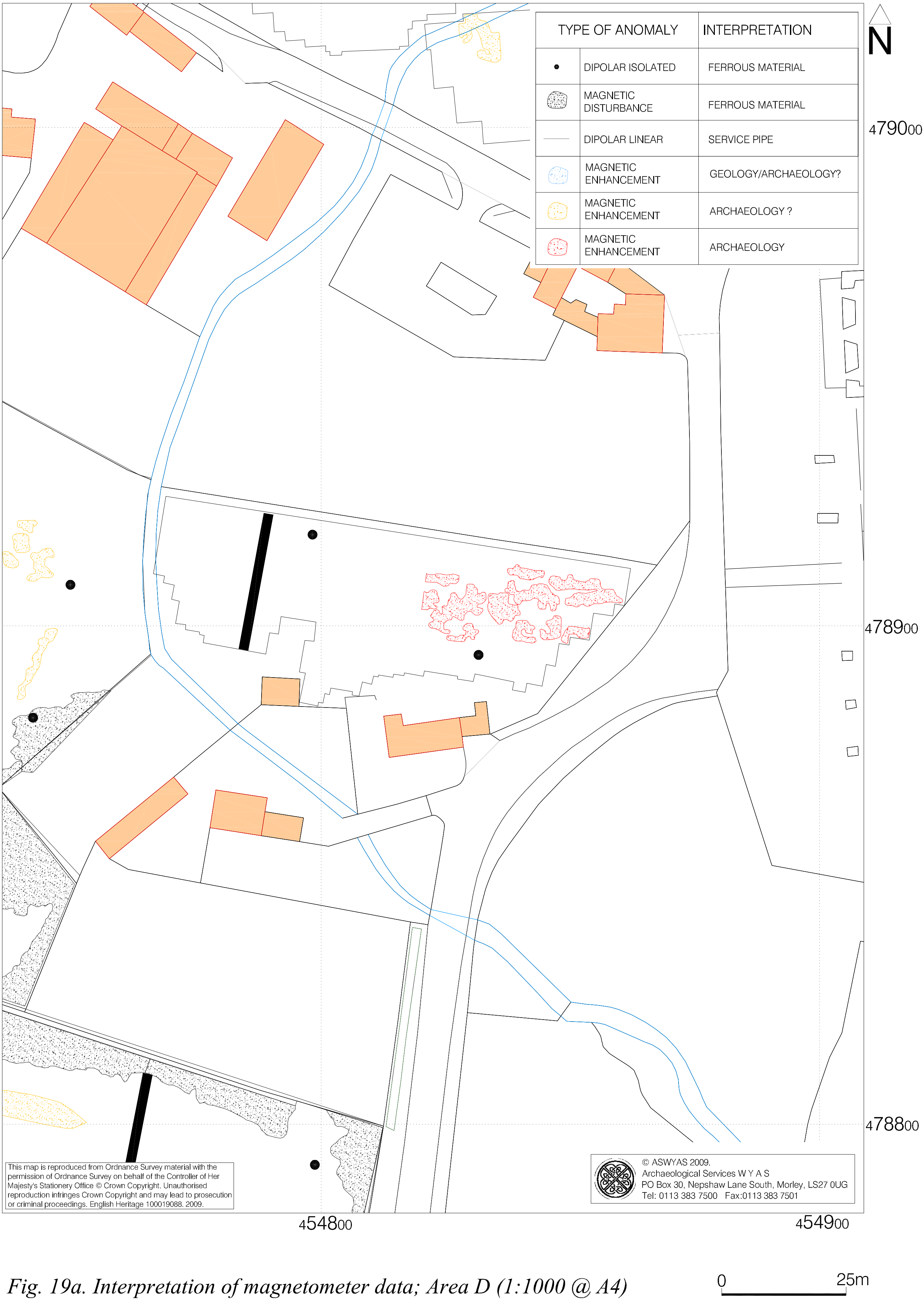

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Fig. 19a. Interpretation of magnetometer data; Area D (1:1000 @ A4)

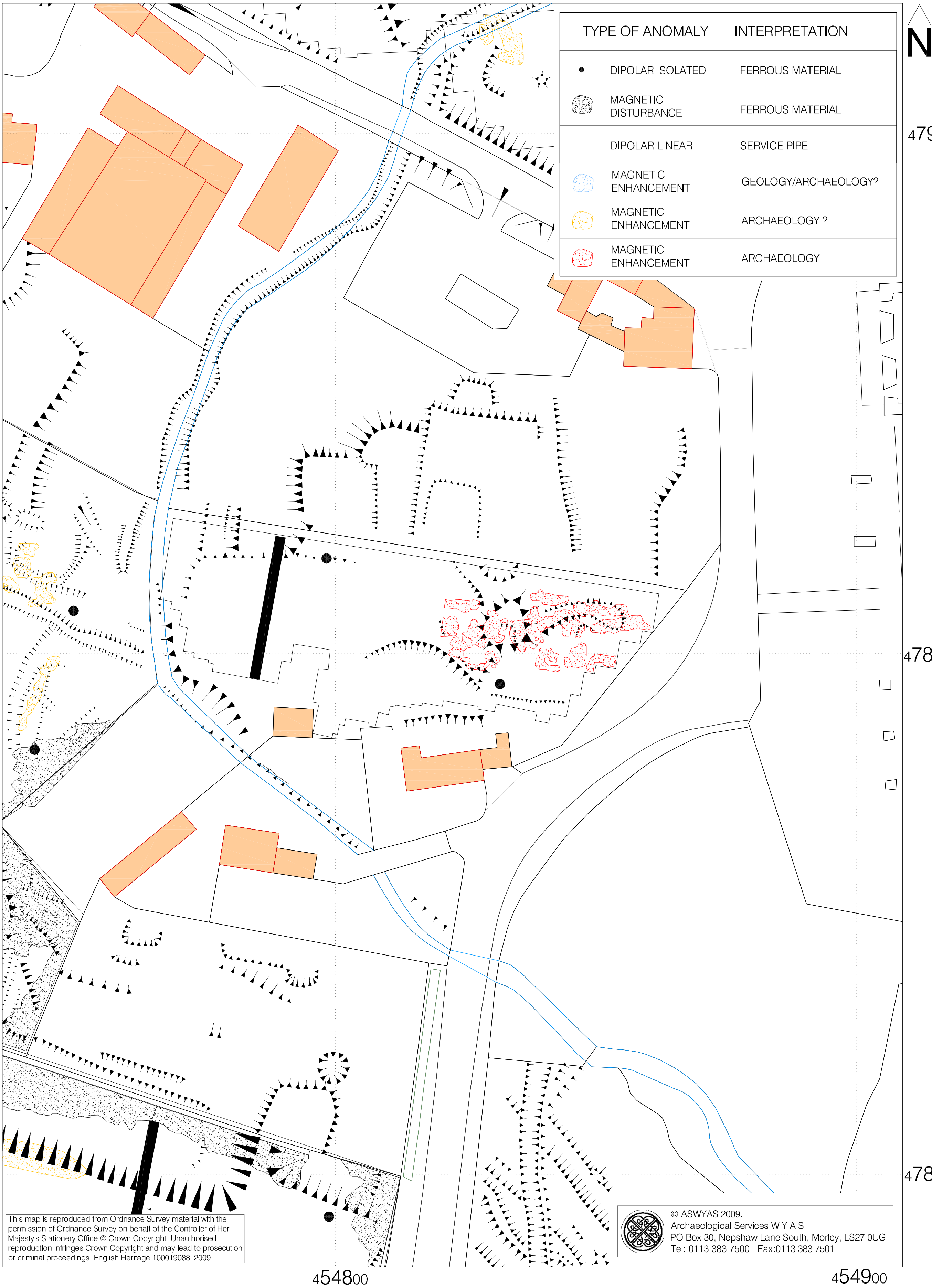

Fig. 19b. Interpretation of magnetometer data and hachured earthwork plan; Area D (1:1000 @ A4)

Fig. 20. Processed greyscale earth resistance data; Area A (1:1000 @ A3)

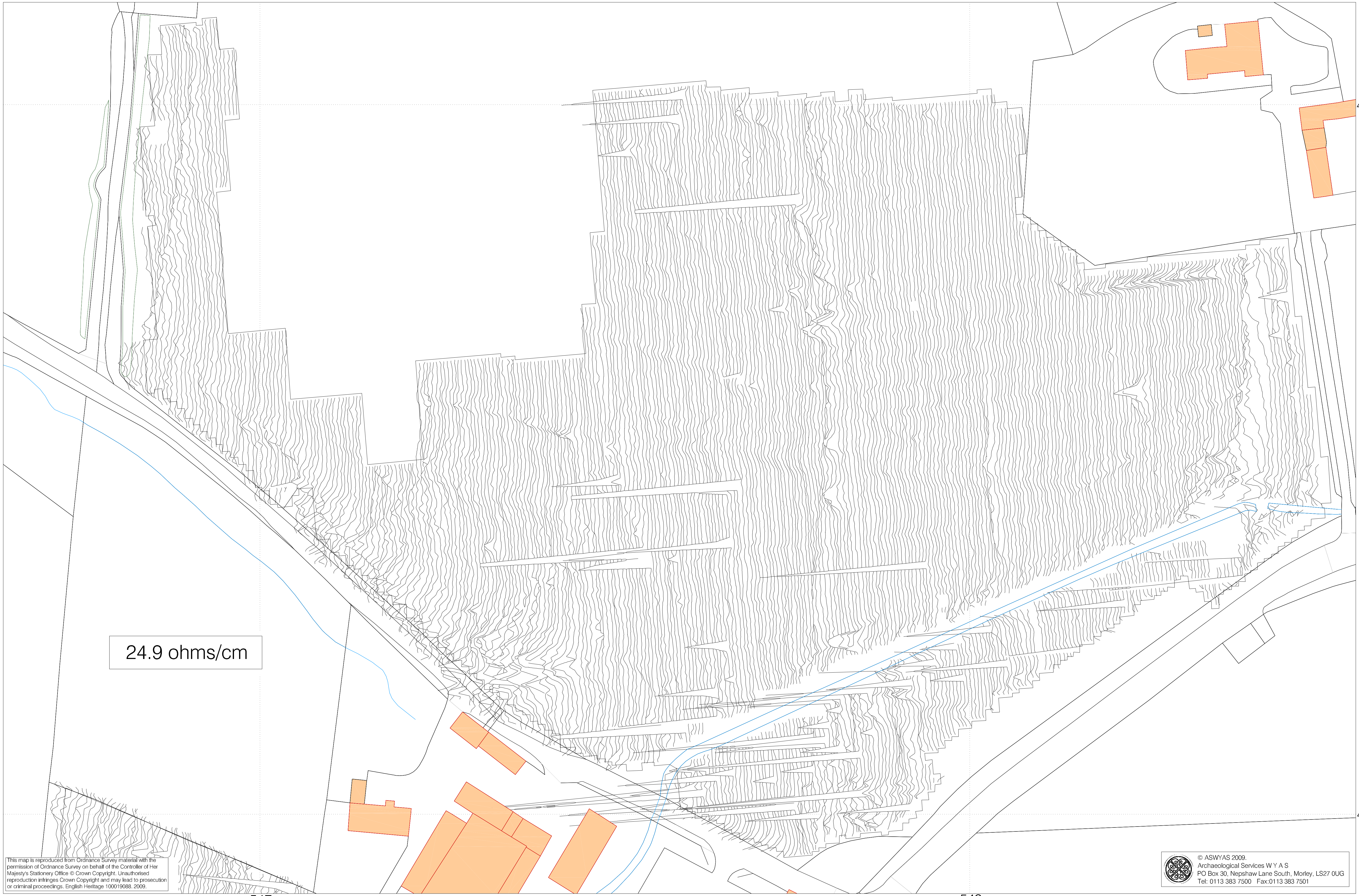

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Fig. 21. XY trace plot of unprocessed earth resistance data; Area A (1:1000 @ A3)

Fig. 22a. Interpretation of earth resistance data; Area A (1:1000 @ A3)

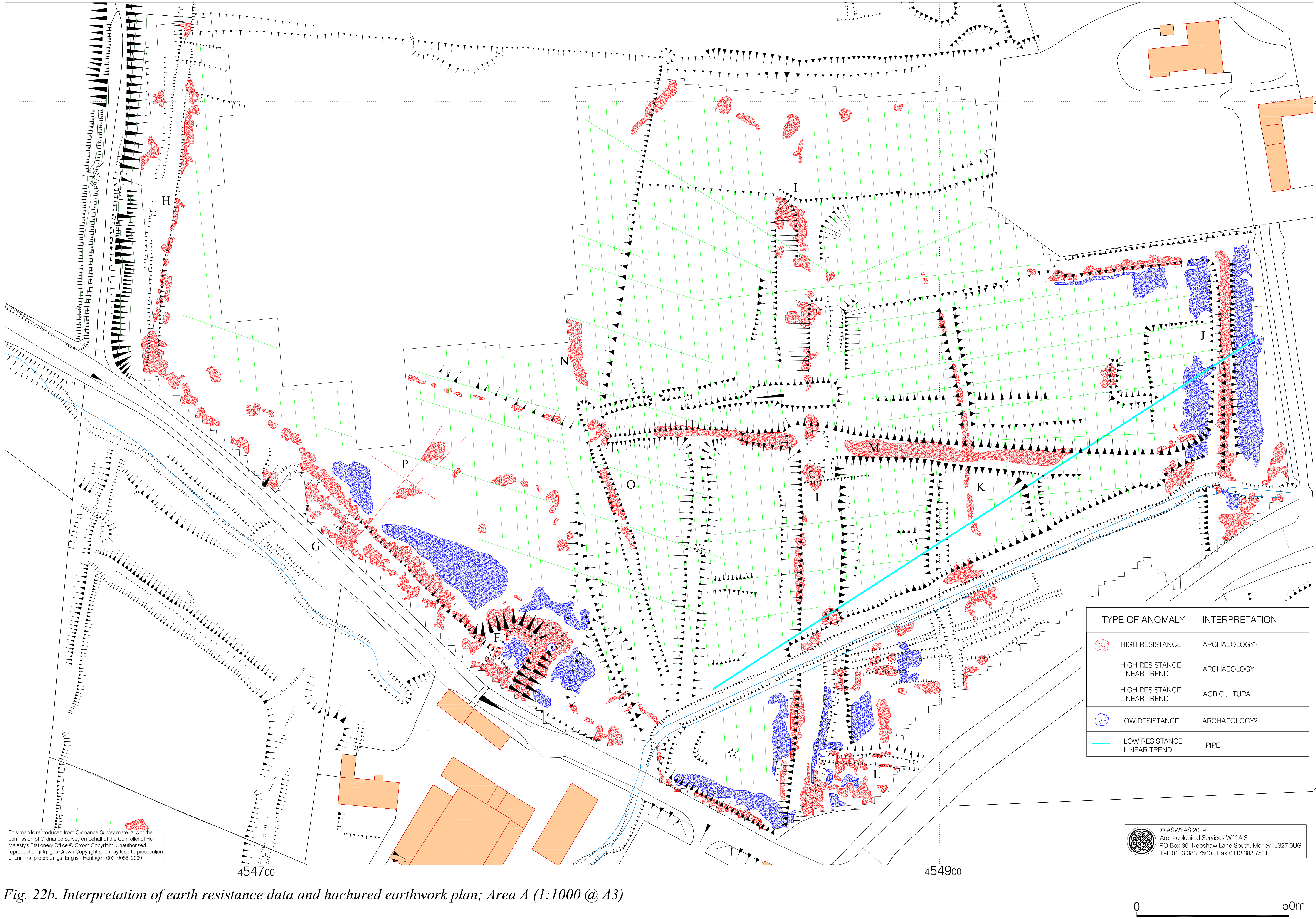

Fig. 22b. Interpretation of earth resistance data and hachured earthwork plan; Area A (1:1000 @ A3)

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Fig. 23. Processed greyscale earth resistance data; Area B (1:1000 @ A4)

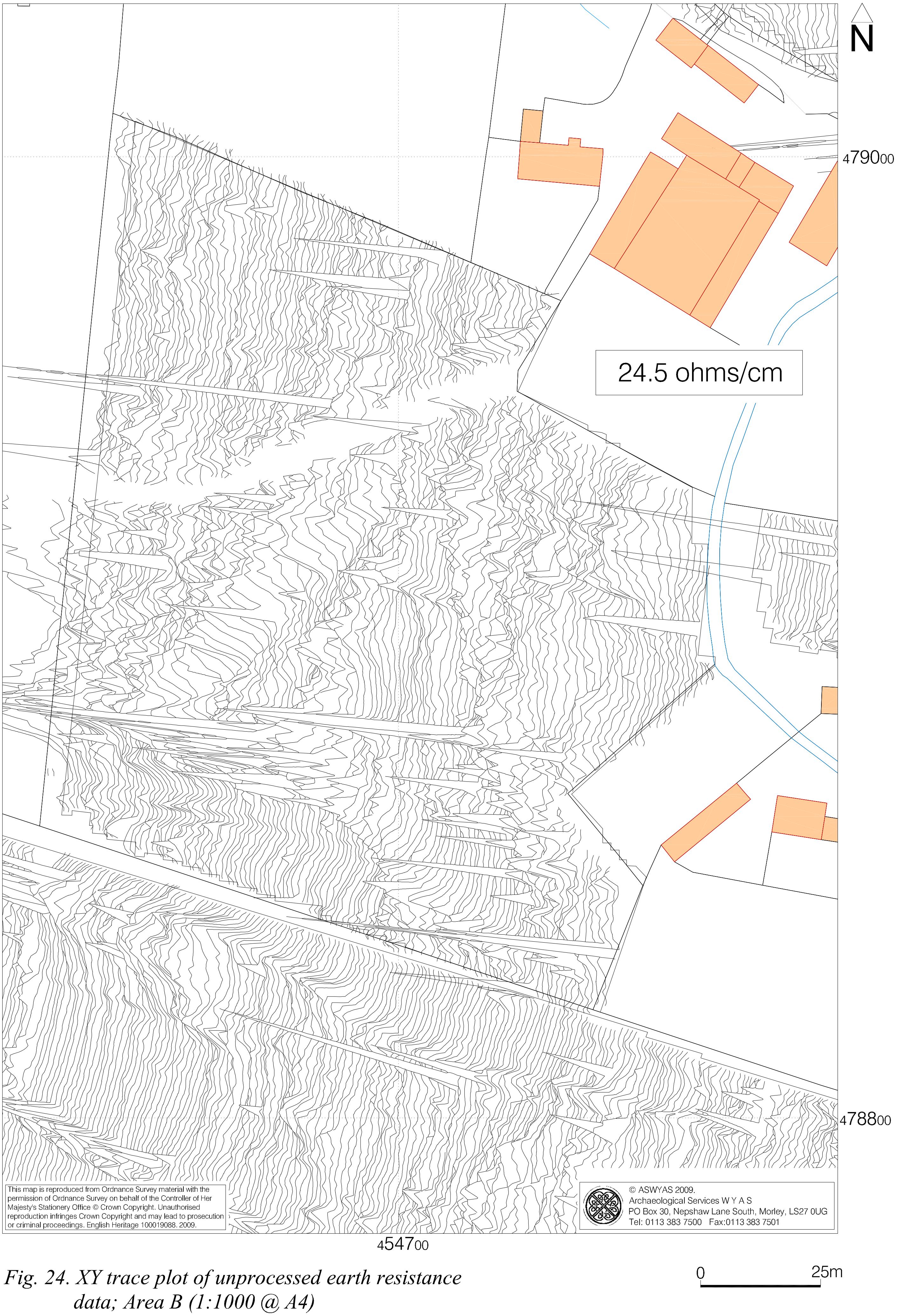

Fig. 24. XY trace plot of unprocessed earth resistance data; Area B (1:1000 @ A4)

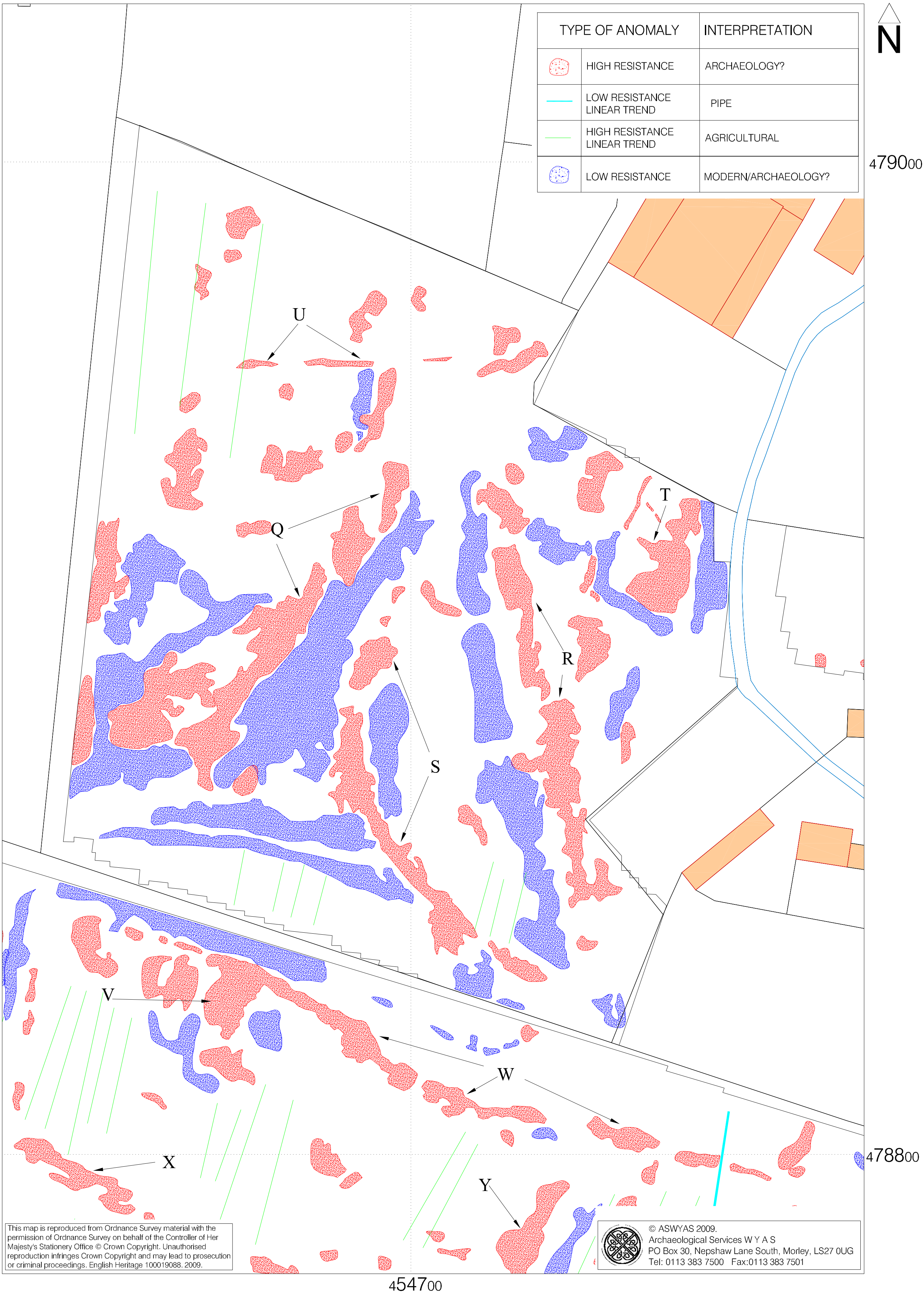

Fig. 25a. Interpretation of earth resistance data; Area B (1:1000 @ A4)

0 25m

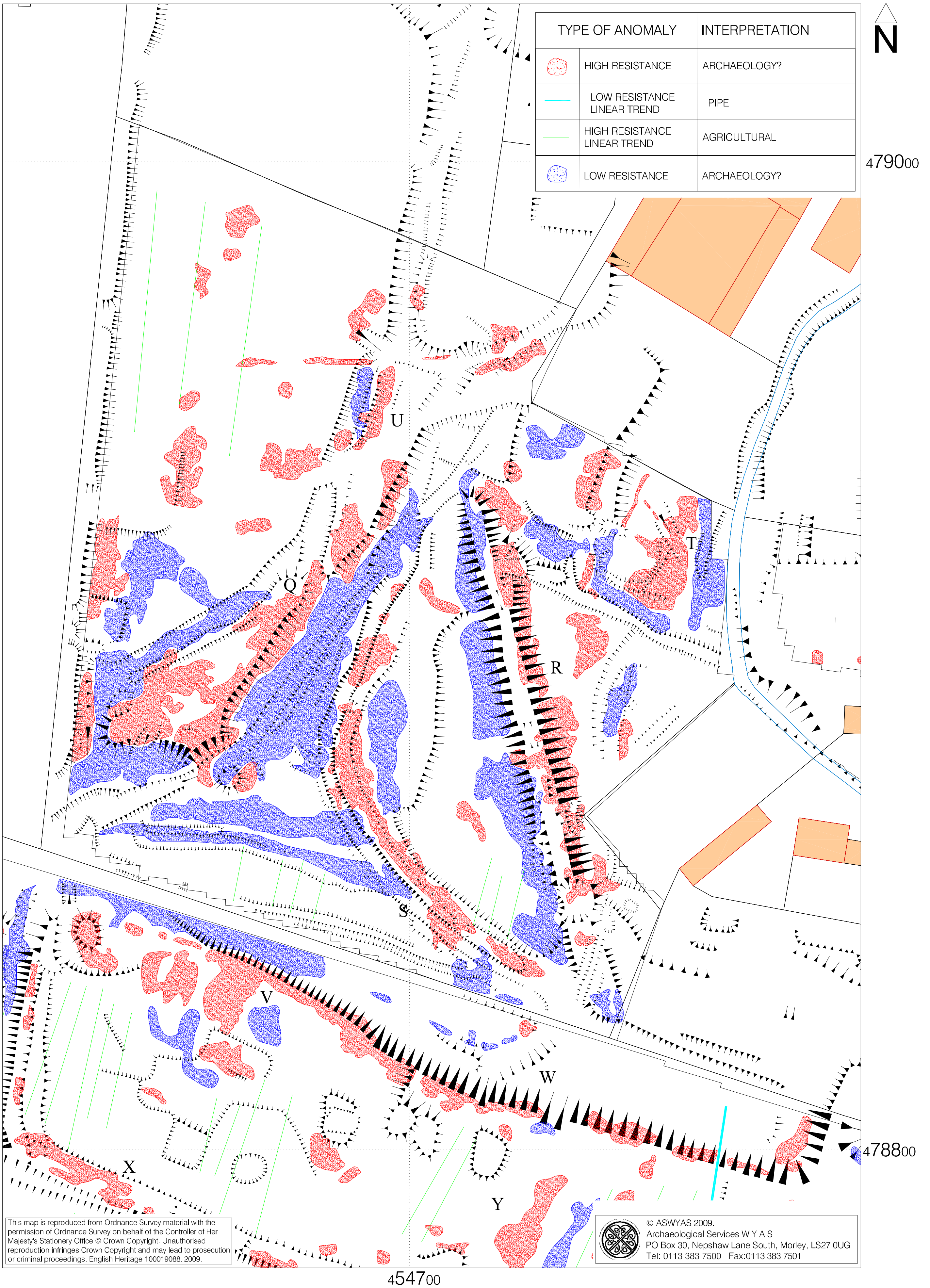

Fig. 25b. Interpretation of earth resistance data and hachured earthwork plan; Area B (1:1000 @ A4)

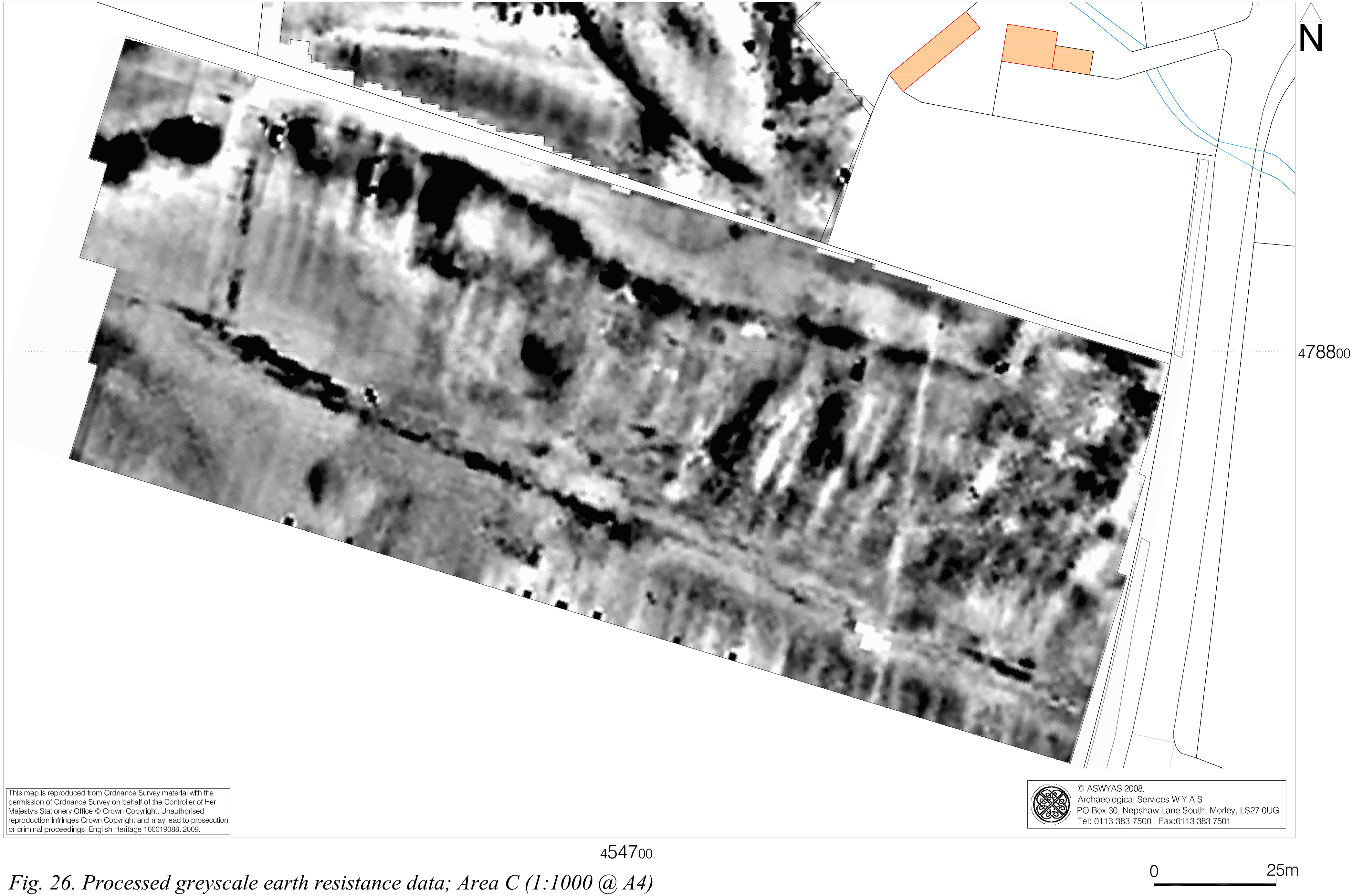

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Fig. 26. Processed greyscale earth resistance data; Area C (1:1000 @ A4)

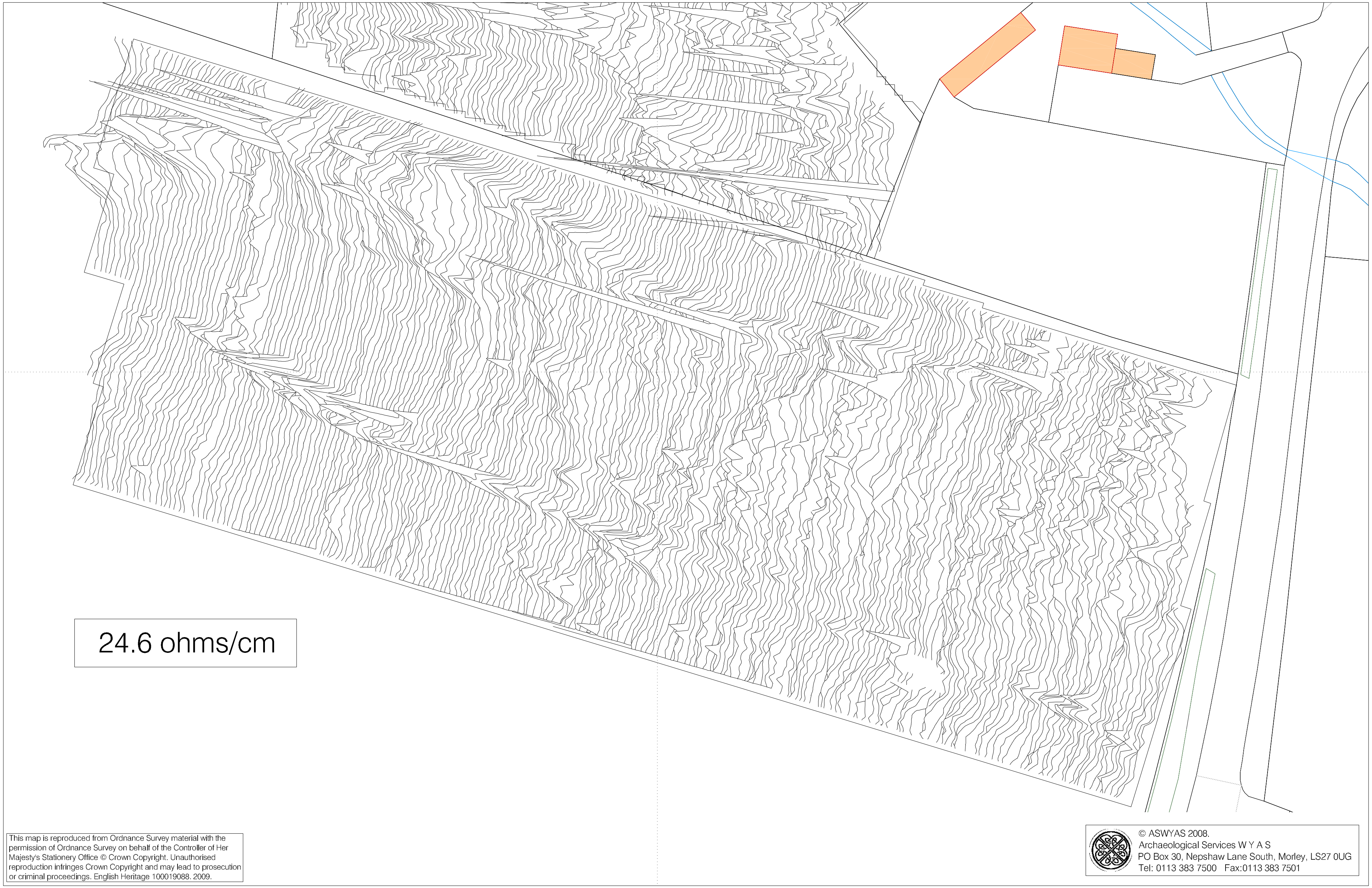

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Fig. 27. XY trace plot of unprocessed earth resistance data; Area C (1:1000 @ A4)

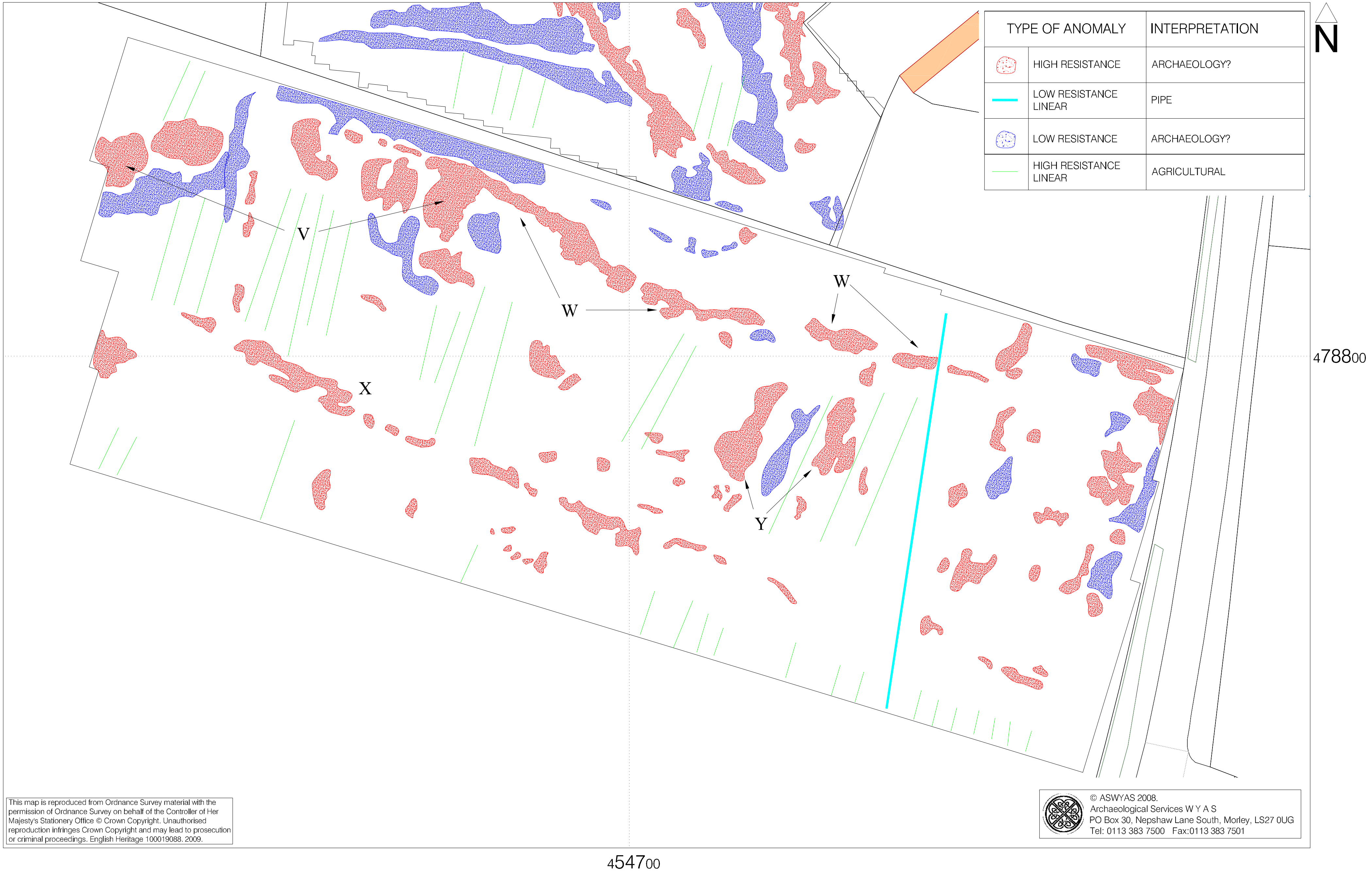

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Fig. 28a. Interpretation of earth resistance data; Area C (1:1000 @ A4)

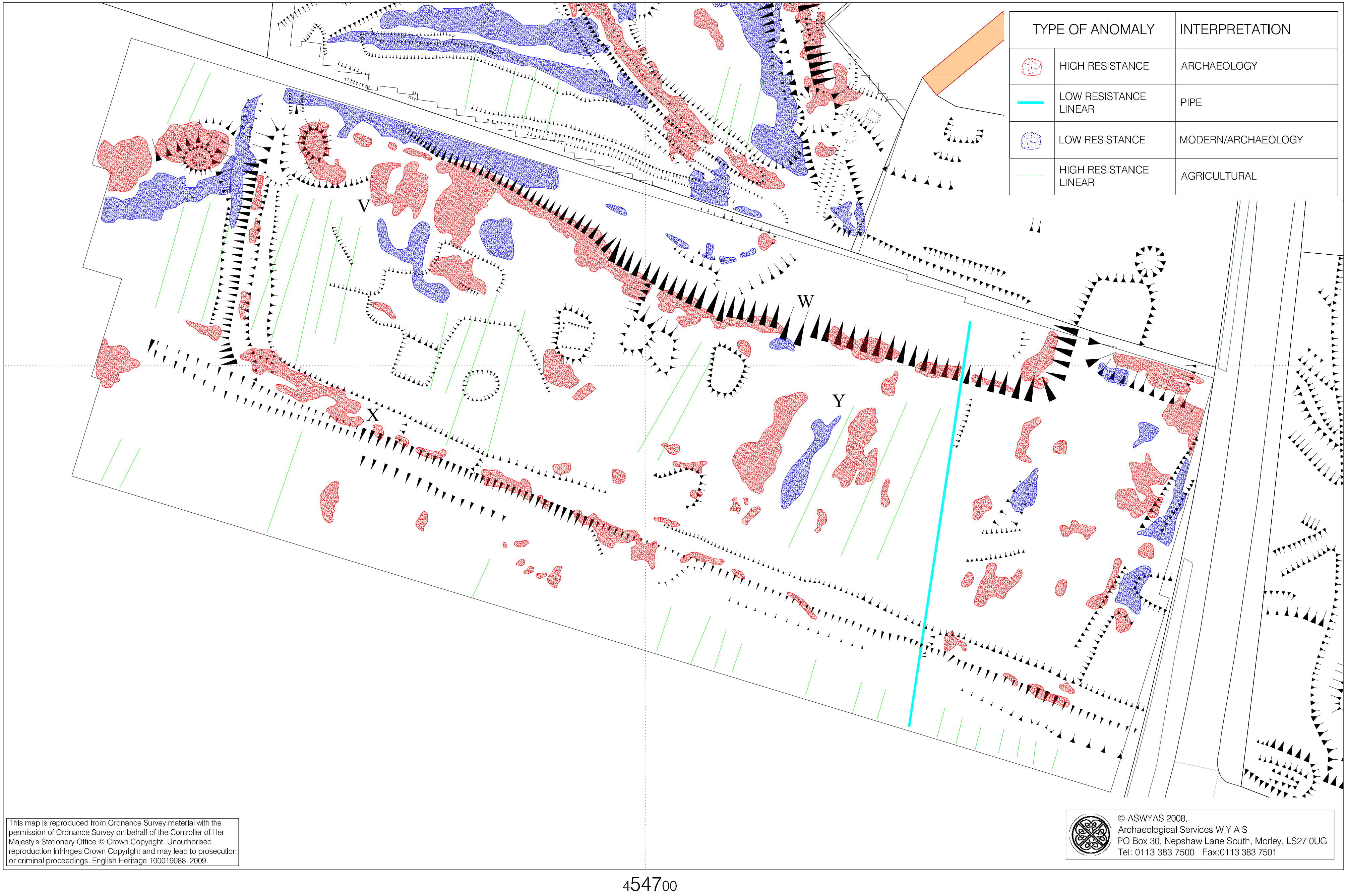

Fig. 28b. Interpretation of earth resistance data and hachured earthwork plan; Area C (1:1000 @ A4)

Fig. 29. Processed greyscale earth resistance data; Area D (1:1000 @ A4)

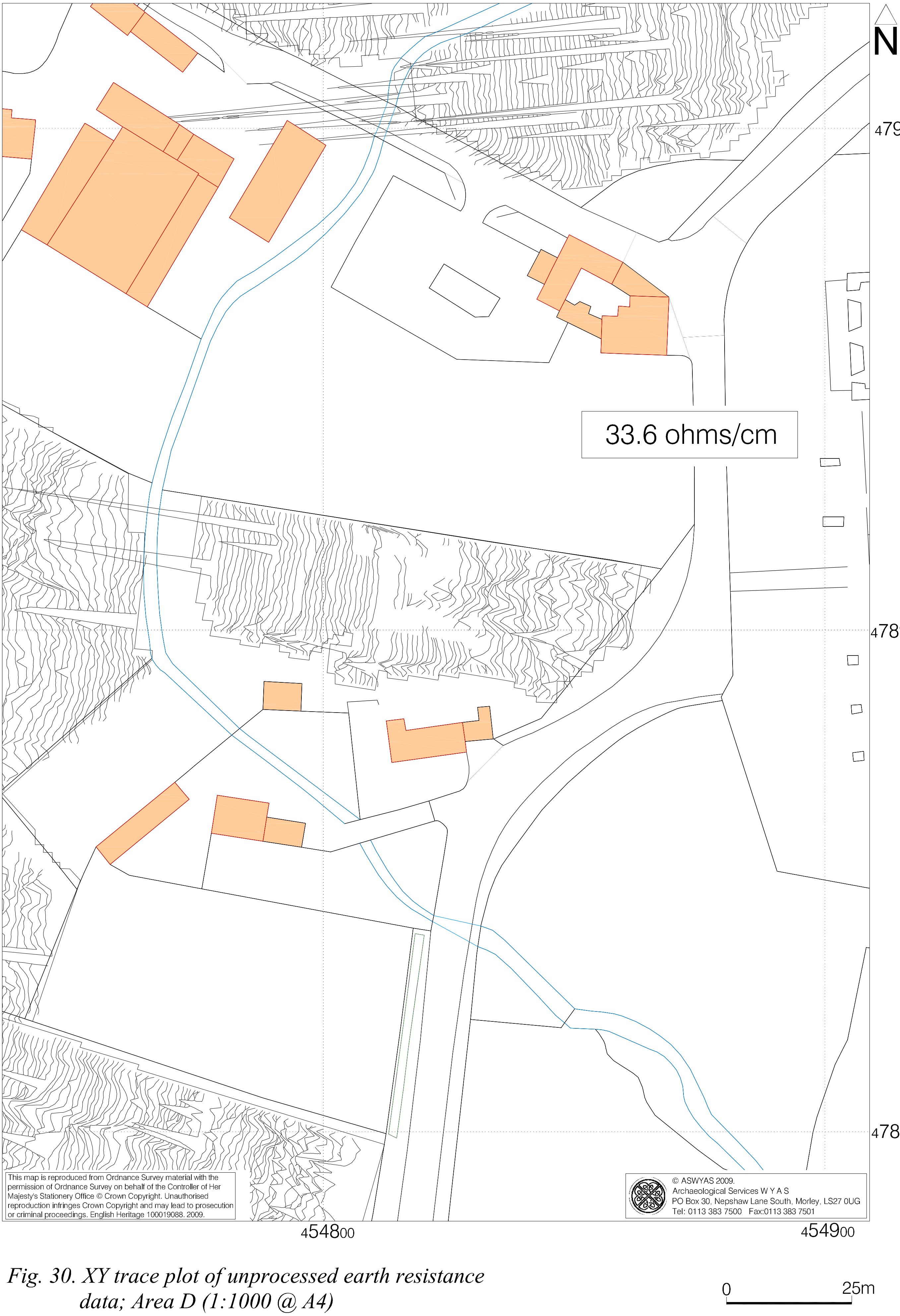

Fig. 30. XY trace plot of unprocessed earth resistance data; Area D (1:1000 @ A4)

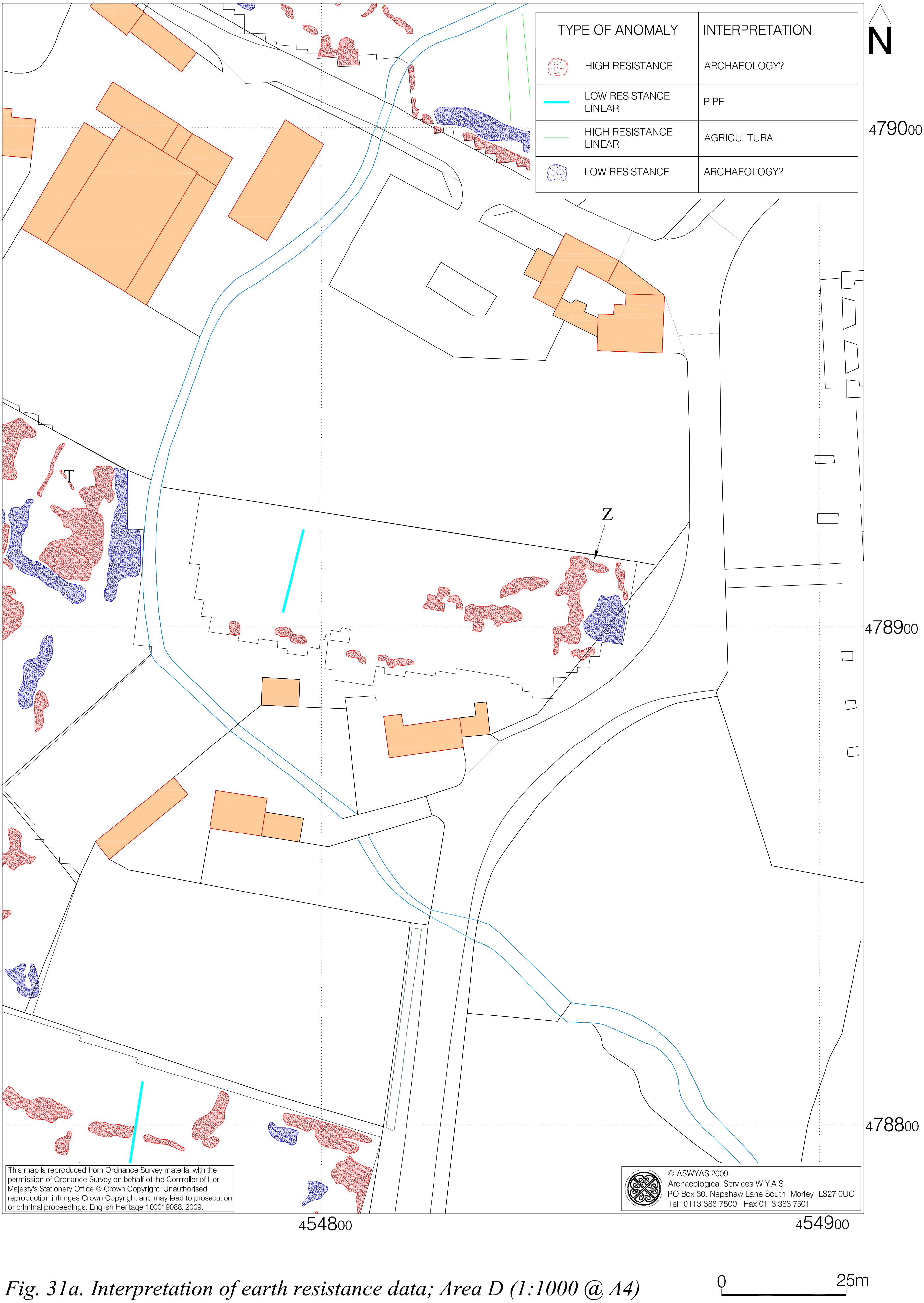

Fig. 31a. Interpretation of earth resistance data; Area D (1:1000 @ A4)

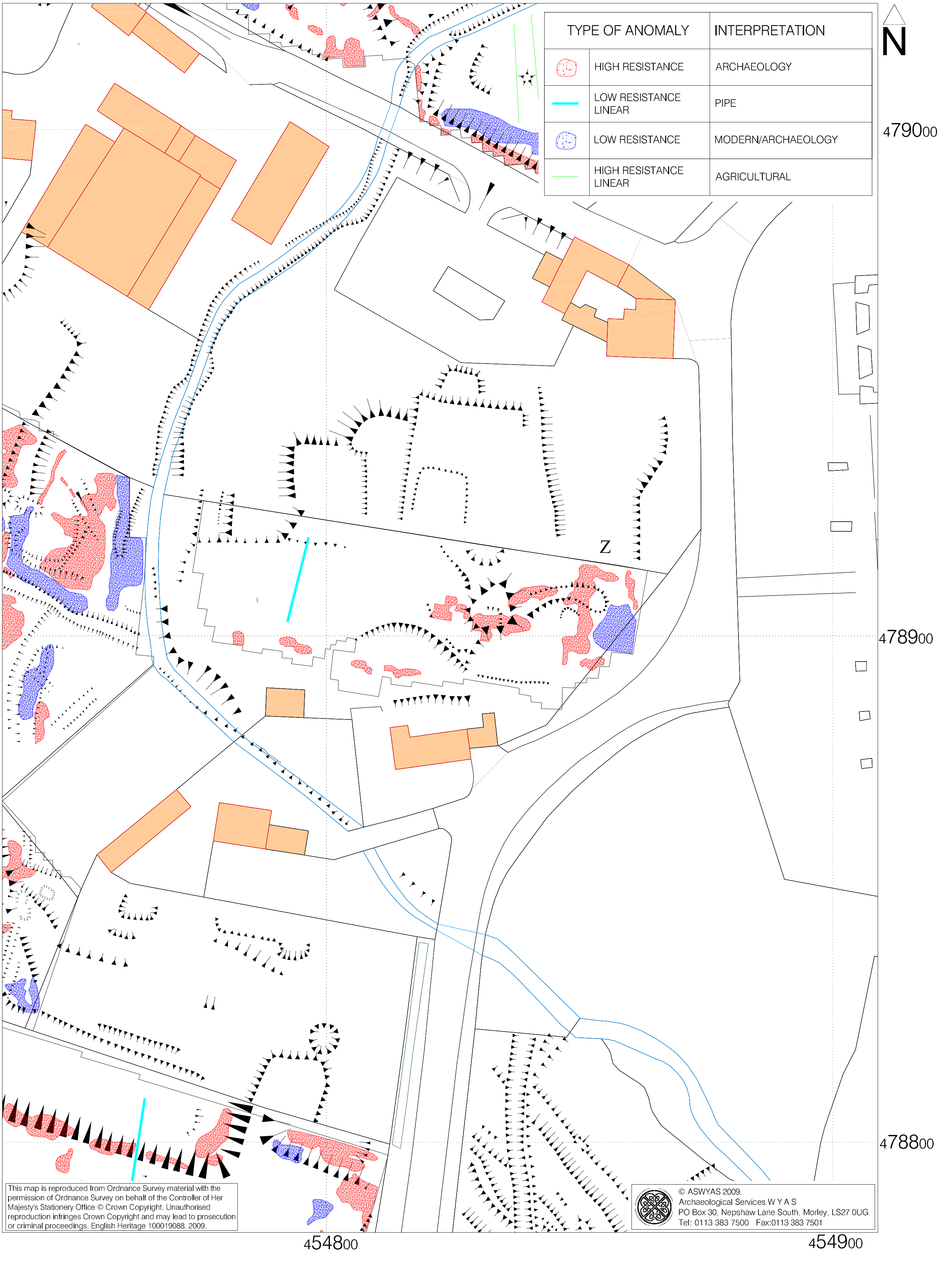

Fig. 31b. Interpretation of earth resistance data and hachured earthwork plan; Area D (1:1000 @ A4)

Plate 1. Remains of wall in Area A with abbey in background looking south-east.

Plate 2. Remains of gatehouse opposite Area A looking south-east.

Plate 3. Earth resistance survey in Area A looking south-east.

Plate 4. Magnetometer survey of Area B looking east.

Plate 5. Earth resistance survey of Area C looking south-west.

Plate 6. Earth resistance survey in Area D looking north-east.

Appendix 1: Magnetic survey - technical information

Magnetic Susceptibility and Soil Magnetism

Iron makes up about 6% of the Earth's crust and is mostly present in soils and rocks as minerals such as maghaemite and haemetite. These minerals have a weak, measurable magnetic property termed magnetic susceptibility. Human activities can redistribute these minerals and change (enhance) others into more magnetic forms so that by measuring the magnetic susceptibility of the topsoil, areas where human occupation or settlement has occurred can be identified by virtue of the attendant increase (enhancement) in magnetic susceptibility. If the enhanced material subsequently comes to fill features, such as ditches or pits, localised isolated and linear magnetic anomalies can result whose presence can be detected by a magnetometer (fluxgate gradiometer).

In general, it is the contrast between the magnetic susceptibility of deposits filling cut features, such as ditches or pits, and the magnetic susceptibility of topsoils, subsoils and rocks into which these features have been cut, which causes the most recognisable responses. This is primarily because there is a tendency for magnetic ferrous compounds to become concentrated in the topsoil, thereby making it more magnetic than the subsoil or the bedrock. Linear features cut into the subsoil or geology, such as ditches, that have been silted up or have been backfilled with topsoil will therefore usually produce a positive magnetic response relative to the background soil levels. Discrete feature, such as pits, can also be detected. The magnetic susceptibility of a soil can also be enhanced by the application of heat and the fermentation and bacterial effects associated with rubbish decomposition. The area of enhancement is usually quite large, mainly due to the tendency of discard areas to extend beyond the limit of the occupation site itself, and spreading by the plough. An advantage of magnetic susceptibility over magnetometry is that a certain amount of occupational activity will cause the same proportional change in susceptibility, however weakly magnetic is the soil, and so does not depend on the magnetic contrast between the topsoil and deeper layers. Susceptibility survey is therefore able to detect areas of occupation even in the absence of cut features. On the other hand susceptibility survey is more vulnerable to the masking effects of layers of colluvium and alluvium as the technique, using the Bartington system, can generally only measure variation in the first 0.15m of ploughsoil.

Types of Magnetic Anomaly

In the majority of instances anomalies are termed 'positive'. This means that they have a positive magnetic value relative to the magnetic background on any given site. However some features can manifest themselves as 'negative' anomalies that, conversely, means that the response is negative relative to the mean magnetic background.

Where it is not possible to give a probable cause of an observed anomaly a '?' is appended.

It should be noted that anomalies interpreted as modern in origin might be caused by features that are present in the topsoil or upper layers of the subsoil. Removal of soil to an archaeological or natural layer can therefore remove the feature causing the anomaly.

The types of response mentioned above can be divided into five main categories that are used in the graphical interpretation of the magnetic data:

Isolated dipolar anomalies (iron spikes)

These responses are typically caused by ferrous material either on the surface or in the topsoil. They cause a rapid variation in the magnetic response giving a characteristic 'spiky' trace. Although ferrous archaeological artefacts could produce this type of response, unless there is supporting evidence for an archaeological interpretation, little emphasis is normally given to such anomalies, as modern ferrous objects are common on rural sites, often being present as a consequence of manuring.

Areas of magnetic disturbance

These responses can have several causes often being associated with burnt material, such as slag waste or brick rubble or other strongly magnetised/fired material. Ferrous structures such as pylons, mesh or barbed wire fencing and buried pipes can also cause the same disturbed response. A modern origin is usually assumed unless there is other supporting information.

Linear trend

This is usually a weak or broad linear anomaly of unknown cause or date. These anomalies are often caused by agricultural activity, either ploughing or land drains being a common cause.

Areas of magnetic enhancement/positive isolated anomalies

Areas of enhanced response are characterised by a general increase in the magnetic background over a localised area whilst discrete anomalies are manifest by an increased response (sometimes only visible on an XY trace plot) on two or three successive traverses. In neither instance is there the intense dipolar response characteristic exhibited by an area of magnetic disturbance or of an 'iron spike' anomaly (see above). These anomalies can be caused by infilled discrete archaeological features such as pits or post-holes or by kilns. They can also be caused by pedological variations or by natural infilled features on certain geologies. Ferrous material in the subsoil can also give a similar response. It can often therefore be very difficult to establish an anthropogenic origin without intrusive investigation or other supporting information.

Linear and curvilinear anomalies

Such anomalies have a variety of origins. They may be caused by agricultural practice (recent ploughing trends, earlier ridge and furrow regimes or land drains), natural geomorphological features such as palaeochannels or by infilled archaeological ditches.

Methodology: Magnetic Susceptibility Survey

There are two methods of measuring the magnetic susceptibility of a soil sample. The first involves the measurement of a given volume of soil, which will include any air and moisture that lies within the sample, and is termed volume specific susceptibility. This method results in a bulk value that it not necessarily fully representative of the constituent components of the sample. For field surveys a Bartington MS2 meter with MS2D field loop is used due to its speed and simplicity. The second technique overcomes this potential problem by taking into account both the volume and mass of a sample and is termed mass specific susceptibility. However, mass specific readings cannot be taken in the field where the bulk properties of a soil are usually unknown and so volume specific readings must be taken. Whilst these values are not fully representative they do allow general comparisons across a site and give a broad indication of susceptibility changes. This is usually enough to assess the susceptibility of a site and evaluate whether enhancement has occurred.

Data Processing and Presentation

The data from the magnetic susceptibility survey has been presented in this report as unprocessed. Mapinfo (Pitney Bowes) was used to display the results as a Thematic Map.

Methodology: Gradiometer Survey

There are two main methods of using the fluxgate gradiometer for commercial evaluations. The first of these is referred to as ***magnetic scanning*** and requires the operator to visually identify anomalous responses on the instrument display panel whilst covering the site in widely spaced traverses, typically 10m apart. The instrument logger is not used and there is therefore no data collection. Once anomalous responses are identified they are marked in the field with bamboo canes and approximately located on a base plan. This method is usually employed as a means of selecting areas for detailed survey when only a percentage sample of the whole site is to be subject to detailed survey.

The disadvantages of magnetic scanning are that features that produce weak anomalies (less than 2nT) are unlikely to stand out from the magnetic background and so will be difficult to detect. The coarse sampling interval means that discrete features or linear features that are parallel or broadly oblique to the direction of traverse may not be detected. If linear features are suspected in a site then the traverse direction should be perpendicular (or as close as is possible within the physical constraints of the site) to the orientation of the suspected features. The possible drawbacks mentioned above mean that a 'negative' scanning result should be validated by sample detailed magnetic survey (see below).

The second method is referred to as ***detailed survey*** and employs the use of a sample trigger to automatically take readings at predetermined points, typically at 0.25m intervals, on zig-zag traverses 1m apart. These readings are stored in the memory of the instrument and are later dumped to computer for processing and interpretation. Detailed survey allows the visualisation of weaker anomalies that may not have been detected by magnetic scanning.

During this survey a Bartington Grad601 magnetic gradiometer was used taking readings on the 0.1nT range, at 0.25m intervals on zig-zag traverses 1m apart within 20m by 20m square grids. The instrument was checked for electronic and mechanical drift at a common point and calibrated as necessary. The drift from zero was not logged.

Data Processing and Presentation

The detailed gradiometer data has been presented in this report in XY trace and greyscale formats. In the former format the data shown is 'raw' with no processing other than grid biasing having been done. The data in the greyscale images has been interpolated and selectively filtered to remove the effects of drift in instrument calibration and other artificial data constructs and to maximise the clarity and interpretability of the archaeological anomalies.

An XY plot presents the data logged on each traverse as a single line with each successive traverse incremented on the Y-axis to produce a 'stacked' plot. A hidden line algorithm has been employed to block out lines behind major 'spikes' and the data has been clipped. The main advantage of this display option is that the full range of data can be viewed, dependent on the clip, so that the 'shape' of individual anomalies can be discerned and potentially archaeological anomalies differentiated from 'iron spikes'. Geoplot 3 and Adobe Illustrator software was used to create the XY trace plots.

Geoplot 3 software was used to interpolate the data so that 3600 readings were obtained for each 30m by 30m grid. The same program was used to produce the greyscale images. All greyscale plots are displayed using a linear incremental scale.

Appendix 2: Earth Resistance Survey - technical information

Soil Resistance

The electrical resistance of the upper soil horizons is predominantly dependant on the amount and distribution of water within the soil matrix. Buried archaeological features, such as walls or infilled ditches, by their differing capacity to retain moisture, will impact on the distribution of sub-surface moisture and hence affect electrical resistance. In this way there may be a measurable contrast between the resistance of archaeological features and that of the surrounding deposits. This contrast is needed in order for sub-surface features to be detected by a resistance survey.

The most striking contrast will usually occur between a solid structure, such as a wall, and water-retentive subsoil. This shows as a resistive high. A weak contrast can often be measured between the infill of a ditch feature and the subsoil. If the infill material is soil it is likely to be less compact and hence more water retentive than the subsoil and so the feature will show as a resistive low. If the infill is stone the feature may retain less water than the subsoil and so will show as a resistive high.

The method of measuring variations in ground resistance involves passing a small electric current (1mA) into the ground via a pair of electrodes (current electrodes) and then measuring changes in current flow (the potential gradient) using a second pair of electrodes (potential electrodes). In this way, if a structural feature, such as a wall, lies buried in a soil of uniform resistance much of the current will flow around the feature following the path of least resistance. This reduces the current density in the vicinity of the feature, which in turn increases the potential gradient. It is this potential gradient that is measured to determine the resistance. In this case, the gradient would be increased around the wall giving a positive or high resistance anomaly.

In contrast a feature such as an infilled ditch may have a moisture retentive fill that is comparatively less resistive to current flow. This will increase the current density and decrease the potential gradient over the feature giving a negative or low resistance anomaly.

Survey Methodology

The most widely used archaeological technique for earth resistance surveys uses a twin probe configuration. One current and one potential electrode (the remote or static probes) are fixed firmly in the ground a set distance away from the area being surveyed. The other current and potential electrodes (the mobile probes) are mounted on a frame and are moved from one survey point to the next. Each time the mobile probes make contact with the ground an electrical circuit is formed between the current electrodes and the potential gradient between the mobile and remote probes is measured and stored in the memory of the instrument.

A Geoscan RM15 resistance meter was used during this survey, with the instrument logging each reading automatically at 1m intervals on traverses 1m apart. The mobile probe spacing was 0.5m with the remote probes 15m apart and at least 15m away from the grid under survey. This mobile probe spacing of 0.5m gives an approximate depth of penetration of 1m for most archaeological features. Consequently a soil cover in excess of 1m may mask, or significantly attenuate, a geophysical response.

Data Processing and Presentation

All of the illustrations incorporating a digital map base were produced in AutoCAD 2008 (© Autodesk).

The resistance data is presented in this report in greyscale format with a linear gradation of values and was obtained by exporting a bitmap from the processing software (Geoplot v3.0; Geoscan Research) into AutoCAD 2008. The data has been processed and has also been interpolated by a value of 0.5 in both the X and Y axes using a sine wave (x)/x function to give a smoother, better defined plot.

Appendix 3: Survey location information

The site grid was laid out using a Trimble dual frequency Global Positioning System (GPS) with two Rovers (Trimble 5800 models) working in real-time kinetic mode. The accuracy of such equipment was better then 0.02m. However, it should be noted that Ordnance Survey positional accuracy for digital map data has an error of 0.5m for urban and floodplain areas, 1.0m for rural areas and 2.5m for mountain and moorland areas. This potential error must be considered if co-ordinates are measured off for relocation purposes.

Station	Easting	Northing
A	454642.302	478853.684
B	454826.844	478988.036
C	454662.701	478780.482
D	454979.403	479086.289

Archaeological Services WYAS cannot accept responsibility for errors of fact or opinion resulting from data supplied by a third party.

Appendix 4: Geophysical archive

The geophysical archive comprises:-

- an archive disk containing compressed (WinZip 8) files of the raw data, report text (Microsoft Word 2000), and graphics files (Adobe Illustrator CS2 and AutoCAD 2008) files.
- a full copy of the report

At present the archive is held by Archaeological Services WYAS although it is anticipated that it may eventually be lodged with the Archaeology Data Service (ADS). Brief details may also be forwarded for inclusion on the English Heritage Geophysical Survey Database after the contents of the report are deemed to be in the public domain (i.e. available for consultation in the relevant Sites and Monument Record Office).

Appendix 5: Section 42 Licence

ENGLISH HERITAGE

YORKSHIRE & THE HUMBER REGION

Mr Mitchell Pollington
WYAS
PO Box 30
Nepshaw Lane South
Morley
Leeds
LS27 0UG

Direct Dial: 01904 601988
Direct Fax: 01904 601999

Our ref: AA/10131/5

17 February 2009

Dear Mr Pollington

Ancient Monuments and Archaeological Areas Act 1979 (as amended) section 42 - licence to carry out a geophysical survey

BYLAND ABBEY, BYLAND, BYLAND WITH WASS, RYEDALE, NORTH YORKSHIRE
Case No:SL00000411
Monument no:13279

I refer to your application dated 13 February 2009, to carry out a geophysical survey at the above site.

English Heritage is empowered to grant licences for such activity and I can confirm that we are prepared to do so as set out below.

By virtue of powers contained in section 42 of the 1979 Ancient Monuments and Archaeological Areas Act (as amended by the National Heritage Act 1983) English Heritage hereby grants permission for geophysical survey of BYLAND ABBEY, for the areas shown on the map that accompanied your application (copy attached). This permission is subject to the following conditions.

1. The permission shall only be exercised by Marcus Jecock and 'nominated representative/s and by no other person. It is not transferable to another individual.

2. The permission shall commence on 17 February 2009 and shall cease to have effect on 17 May 2009.

3. A full report summarising the results of the survey and their interpretation shall be sent to Beki Burns and to Paul Linford of the English Heritage Geophysics Team at Fort Cumberland (Fort Cumberland Road, Eastney, Portsmouth,

Hampshire, PO4 9LD), no later than 3 months after the completion of the survey.

You are also asked to complete and return the enclosed questionnaire about the survey to the Geophysics Team, Fort Cumberland (address as above), in order to assist with maintenance of our national database of geophysical surveys. Information from this questionnaire will be entered onto our database as a preliminary record which would be updated when you send to us a copy of the full report. If the work is to be done by a contractor could you please pass the form on to the surveyor.

Being part of our survey database, some details of your survey will be made publicly accessible on the Internet, although no images or data sets will be included. We will assume you have no objection to this unless you let us know to the contrary.

4. Copies of the report should be sent to: Dr. Mark Douglas, English Heritage, 37 Tanner Row, York, YO1 6WP; Lousie Martin of English Heritage Geophysics Team at Fort Cumberland (Fort Cumberland Road, Eastney, Portsmouth, Hampshire, PO4 9LD; Marcus Jecock of English Heritage, 37 Tanner Row, York, YO1 6WP.

This letter does not carry any consent or approval required under any enactment, bye-law, order or regulation other than section 42 of the 1979 Act (as amended).

You are advised that the person nominated under this licence to carry out the activity should keep a copy of this licence in their possession in case they should be challenged whilst on site.

Yours sincerely

BR

Beki Burns
Casework Assistant
E-mail: rebecca.burns@english-heritage.org.uk
cc

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